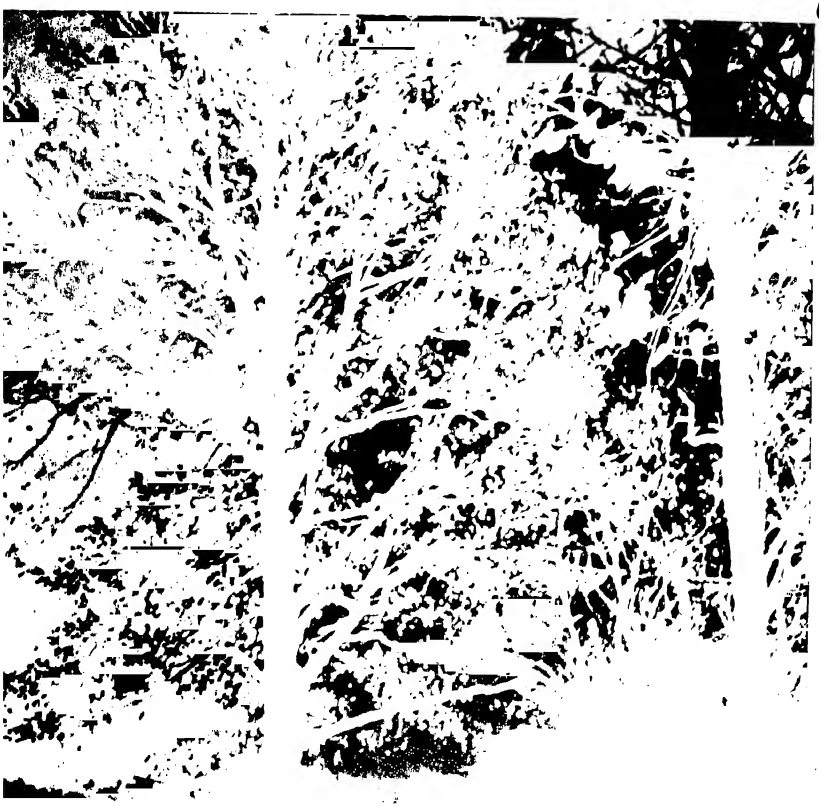


A world of hidden living things.

THE LIVING WORLD

BY

SAMUEL H. WILLIAMS
Professor of Zoölogy in the University of Pittsburgh and Associate Director of the University Lake Laboratory

NEW YORK
THE MACMILLAN COMPANY

PRINTED IN THE UNITED STATES OF AMERICA
BY THE FERRIS PRINTING COMPANY

PREFACE

The lack of organization and the proper distribution of emphasis have been the two major difficulties in the teaching of a general course in nature. In designing a textbook for such a course the author is faced with the problem of organizing and properly emphasizing a vast amount of material. In view of the great amount of literature required in the proper pursuit of a course in natural science, a textbook must be constructed so as to collate and coördinate the factual and the methodological principles involved. This text attempts to meet the manifold needs of a general course. It is presented first as a course of study and secondly it involves a method of procedure. It is designed to fulfill the requirements of a cultural course in biology and to serve as a basic text in Nature Study, Field Biology, and Elementary Ecology Courses. Inasmuch as investigative studies are recommended, the bibliography is rather extensive. The reference literature has been carefully selected from the thousands of available books and papers pertinent to the subject. In order to keep the book within proper bounds, it has been necessary to curtail extensive discussions of many things that could be attractively elaborated. It is hoped, however, that the work will point the way toward a happy understanding of the biotic world.

A classification of the animal world and a simplified classification of habitats have been included after serious consideration. In almost twenty years of teaching natural science courses, the author has encountered the need of readily available schemes of this kind, especially in field and laboratory studies. The insertion of scientific names is for the purpose of avoiding confusion. Frequently a common name is applied to a number of different species and sometimes an individual has numerous common names. The species are indicated to show definitely what is meant. The diversity of content precludes the desired smoothness of continuity, perhaps, but it seemed best to present each phase of the subject in a unit discussion. The text is, in a way, a pioneer in its field and the usual crudities of pioneer work are probably evident. The method, however, has been thoroughly tested in college, univer-

sity, and teachers' college classes and also in courses given at the University of Pittsburgh Biological Station on Lake Erie.

The author is indebted to many persons for assistance in the preparation of the work. To my assistants, Mr. George J. Dambach, Mr. Lee W. Henderson, Jr., and Mr. G. E. Wallace much credit is due. Mr. Dambach who has worked with me at the University biological station and in the Amazonian jungles, has helped greatly in preparing illustrations and he is responsible for most of the original photographs included. Mr. Henderson has worked tirelessly in the checking of bibliographies and in reading proof. Mr. Wallace assisted in organizing the Hymenoptera into major groups. I cannot thank these men enough for what they have done.

Misses Virginia Means, Martha Fuller, and Dr. Edna Higbee have typed the manuscript in its various forms. Messrs. Hershel Stone, Johann Melassonos, and Alexander Varlashkin have rendered mechanical assistance which is greatly appreciated.

Mr. M. Graham Netting of the Carnegie Museum read the chapters on Amphibians and Reptiles. Dr. Stanley T. Brooks also of the Carnegie Museum has offered some valuable suggestions and supplied the excellent drawings of snails. With his wife, Dr. Betty Watt Brooks, he prepared the key to the land snails. Mr. R. L. Fricke of the Carnegie Museum generously supplied the pictures of birds' nests; Dr. A. W. Lindsey of Denison University read the chapter on Insects and offered some helpful suggestions. Professor Andrew Lester of Frick Teachers' College read and criticized the chapter on Spiders. Dr. O. E. Jennings, Head of the Biology Department of the University of Pittsburgh and Curator of Botany at the Carnegie Museum, read the chapters on Plants and Trees, and his criticisms were very helpful. Professor R. A. Waldron of Slippery Rock Teachers' College and Mr. J. K. Doutt, of the Carnegie Museum made some splendid suggestions. Mr. John G. Mock, Outdoors Columnist of the Pittsburgh Press, suggested a few of the questions included in the list in Appendix B.

To all of these the author is deeply grateful.

In illustrating the text, the author has had to depend upon the generosity and professional spirit of numerous authors and publishers. In few countries of the world will one find such a spirit of helpful coöperation as is evidenced by the writers and publishers in the United States. The following persons and institutions have

graciously contributed illustrations which are duly acknowledged. Dr. and Mrs. A. H. Wright and Dr. A. A. Allen of Cornell University; Dr. E. M. Gress, State Botanist of Pennsylvania; Miss Fern L. Taylor supplied the drawings of galls; Dr. Andrey Avinoff, Director of the Carnegie Museum; Messrs. W. Gard Conklin and James Morton of the Penna. Game Commission technical staff; the Hon. O. M. Deibler, Commissioner of Fisheries in Penna.; Mr. Harry Stackpole, Secretary of the Penna. Board of Fish Commissioners; Drs. F. E. Lutz and Frank M. Chapman of the American Museum of Natural History; Dr. Austin H. Clark of the Smithsonian Institution; Dr. C. C. Adams and the N. Y. State Museum; Dr. Raymond L. Ditmars and W. H. Bridges of the New York Zoological Society; Dr. H. H. Ross and the Illinois State Laboratory of the Natural History; Dr. Bristow Adams and the Cornell Agricultural Experiment Station; Dr. Joseph S. Illick of the N. Y. State College of Forestry; Dr. Homer H. Will and the Penna. Academy of Science; the Penna. Department of Forests and Waters; Denoyer Geppert & Co.; The General Biological Supply Co.; the Directors and Staffs of the Bureaus of Entomology and the Biological Survey in the U. S. Department of Agriculture. To all of these the author expresses his grateful thanks.

To the following publishers and to the authors of the books they have published, the writer cannot adequately express his feelings of gratitude. To all of them he extends the privilege of using any or all of the original illustrations included in the text as well as others in his possession. The publishers who have generously extended courtesies are: The Macmillan Co.; Ginn & Co.; Henry Holt & Co.; P. Blakiston's Son & Co.; D. Appleton-Century Co., Inc.; G. P. Putnam's Sons; John Wiley & Sons; McGraw-Hill Book Co.; D. Van Nostrand Co., Inc.; Carnegie Museum; and the University of Pittsburgh Press.

To the officials and editorial staff of The Macmillan Company the author extends heartfelt thanks for their coöperative and tolerant consideration.

For the numerous errors and oversights which are no doubt present in the work, the author assumes full responsibility.

SAMUEL H. WILLIAMS

TABLE OF CONTENTS

CHAPTER X

LIST OF ILLUSTRATIONS

PLATES

PART I

THE BIOLOGICAL ASPECTS OF LIVING THINGS

CHAPTER I

THE STUDY OF NATURE

In attempting to present all of the biological phases of nature in a single text, the author is not unaware of the almost impossible demands of such an endeavor. This work is not designed solely from the standpoint of imparting information. To incorporate a vast amount of information on the subject-matter here entertained would necessitate a book of unwieldy proportions. An attempt has been made to include the fundamentals and to omit information that is readily available in scores of elementary textbooks and numerous manuals. Furthermore, information as such is hardly justifiable. Unless the book prepares the student of nature for pursuing the study entirely on his own, it will miss its aim. After all, the investigative habit is the fundamental basis of science; and it should be clear in the beginning that there is a vast fund of information about the principles and organisms mentioned here—so vast that the life span of humans is not sufficient time to acquire all of the known facts. Numerous volumes have been written on many of the individual subjects discussed in this text. It would be utterly impossible to incorporate extended discussions of many individual groups of organisms in a book of this kind.

The informational emphasis also precludes methodical procedures. To learn the birds, insects, or mammals of a region without study of the application of principles to them would render the student helpless if he were to change the scenes of his investigations. The principles are universal. They apply to life in the tropics as well as to life in the arctic regions. To know the principles of interpretation makes it possible for anyone to gather information quickly, no matter where. This text is constructed with the idea of indicating what is to be learned; and where and how to get this information. It is hoped that the cardinal principles of life in its various forms will be revealed and that the student will be prepared to pursue the study of nature with confidence, enthusiasm, and with an understanding heart.

By the student is meant anyone who has the desire to become familiar with plants and animals as they are related to each other and to their environment. A brook becomes a world of life to the initiated. It represents a society of its own with a diverse populace, the success of which depends upon conformity to the laws of nature and upon the recognition of its limitations by every individual. In it are enacted daily the dramas, melodramas, and comedies characteristic of life as we know it. Hatreds, feuds, coöperation, work, play, and the eternal struggle for existence define the scope of activity of each inhabitant. The weaker perish, and even the strong often succumb to the calamities of fate.

The study of nature must be practical as well as theoretical. The joy comes of seeing the principles at work. Therefore this book is essentially a guide. It is not merely a textbook of zoölogy, botany, or descriptive ecology. It should serve to point the way toward the full and happy pursuit of satisfying an intellectual curiosity about the world in which we live. The author hopes that the limited information incorporated in it will stimulate that curiosity. If it does this, and if the principles are presented in an understanding way, the student has a lifetime program before him—a program so diverse as to hold the interest and never grow tiresome.

One book could not suffice for the complete study of nature in the field or in the laboratory. References and special works will be necessary. These are listed in the bibliographies at the ends of the various chapters. Works of purely local interest can be suggested by the teacher. This text presupposes collateral reading, outside investigative assignments, and field studies. The flexibility of the text allows for the expansion of any phase of particular local interest. In schools where extra time is devoted to the subject, the individual groups can be studied in more detail.

Teachers should find the method useful for increasing the scope of their own knowledge; and it is hoped that there will be many suggestions for expanding any course in nature study, whether it be elementary or advanced. Mere identities are insufficient; such questions about an organism as those listed below should be asked and answered as far as possible. Where does it live? What kind of a home does it make? Is it active all year? What does it eat? Is it solitary, gregarious, colonial, or social? How is it adapted to the situation in which it lives? What are its habits?

What relationships exist between sexes or among the group? How is it affected by the physical environment? How does it secure its food? What are its defenses? These and numerous others, many of which are asked and answered throughout the book, are vastly more important than the name of the plant or animal.

The term Nature Study too often suggests something elementary, but it has many phases. It may be elementary, or it may be extremely advanced and involved; just as mathematics has a graduated scale of comprehensiveness. A problem in simple fractions is as difficult to the fifth-grader as a problem in shell trajection is to the college student of calculus.

The most difficult part of science is the interpretation of results. The naturalist attempts to interpret nature in nature, where the regulating influences are difficult to discern and where numerous factors obtain. This is much more difficult than interpreting results in an experiment where all other factors are under control.

It often happens that the average person, and even school children, know more about African lions, Australian kangaroos, and Rocky Mountain sheep than they know about the common animals in the neighborhood in which they live. It is regrettable that so many people have the idea that in order to see the wonderful things in nature they must travel to Africa, to the South American jungles, or to almost any place just so it is far away from where they are; when in reality life is just as interesting and much more accessible in any American countryside. Most of us are "too close to the forest to see the trees," and we overlook the interesting possibilities at our feet. The campus or school yard; the flower or vegetable garden; the neglected city lot; the shade trees that line the streets, not to speak of city parks and suburban areas about great cities—all provide an abundance of material for the naturalist. And this material, when properly interpreted, reveals some of the most interesting observations on adaptations, interrelationships, and the other biological principles discussed in this text.

Happiness through nature. One does not have to travel to distant lands to find happiness in nature, for here at home—no matter where that may be in these United States—the animals and plants are just as interesting in their structural makeup and in their living as the animals and plants anywhere in the world. With few excep-

tions, our butterflies are just as brilliant; our ants do just as many interesting things; our animals exhibit just as many interesting and diverse protective devices and behaviorisms; our lizards shed their tails in order to escape just as they do in the tropics; our plants bear flowers that are just as beautiful, and they possess just as many interesting devices for insuring their perpetuity; our insects sing just as many interesting songs and they display as many unique methods of courtship as those found in the heart of the Amazon jungles.

It all depends upon the point of view and upon the development of the powers of observation and understanding. To that end this text was written. Field observations are urged to convince the "doubting Thomases" of the veracity of these claims.

As for children, they need only to be intelligently introduced to nature in order to arouse their interest. They are themselves such an integral part of nature that the birds, trees, flowers, and insects hold for them a commanding interest that will divert their attention from questionable forms of entertainment and fill the hours of undirected activities with wholesome pursuits.

The scope of the subject. A comprehensive and useful study of plants and animals must include many things: (1) A classification of plants and animals is necessary for the study of relationships; this is the way of determining individual identities. (2) The study of habitat selection and the adaptations of forms to environmental conditions develops a knowledge of where animals live and are to be found. (3) The study of the modifications of structures, physiological processes, and life histories in response to environmental demands, develops the interpretative ability of the student. (4) The effects of physical and chemical environmental factors such as light, temperature, chemical nature of the media, and humidity, on the habits, behaviorisms, and adjustments of plants and animals stimulate continued interest. (5) A knowledge of defenses, limits of adjustment, seasonal succession, reproductive cycles and capacities, food, and the numerous possible interrelationships among animals and between the animals and plants contributes to a thorough understanding of life and the principles involved in its survival, diversification, and distribution.

In brief, the student, after having finished the course, should know a great many organisms in different groups. He should know their habits, life histories, defenses, sex relationships, periodic

FIG. 1. The pond is a world of living things.

activities, and economic values. In addition, the serious-minded student will learn considerable about the social, parasitic, symbiotic, and predatory habits of animals and through these studies the bases of animal associations will be, in part, revealed.

This is a huge undertaking, only a fraction of which is possible of achievement. But the principles of interpretation will be learned; and as time passes, the "embryo naturalist" will mature. The acquisition of facts throughout future years, combined with that feeling of "being close to nature"—understanding her "various language"—will contribute to a happiness which only the initiated can enjoy. And what is more, the lessons taught by nature will reveal that man himself is a part of the cosmic scheme; an object for the brutal forces of nature to attack; a competitive member of the living association. With this knowledge, man should live more efficiently; he should more easily combat destructive forces; and he should more intelligently solve the problems of society.

The Kinds of Living Things

There are a great many organisms in the world. Some of them are large, others are small; some are beautiful, others are grotesque; some of them are harmless, while others are dangerous; many of them seriously menace man's welfare, while others are his closest allies in the struggle for existence. Some of these organisms man eats; others would and do eat man if and when opportunities to do so arise. All of these organisms belong either to one or the other of two existing categories—*plant* and *animal*.

The obvious differences between the higher members of these two divisions of the living world, such as between a tree and an elephant, for instance, would indicate that the two kinds of organisms have little in common. However, a careful scrutiny of the plant and animal worlds shows the difficulty of establishing a set of distinguishing characteristics by which each may be positively identified. A living organism can be easily distinguished from a non-living one by its definite size, definite form, irritability and its capacity for reproduction. These properties apply to plants as well as to animals. There are large animals, such as hippopotami; and there are microscopic ones, such as protozoans. There are large plants such as trees, and invisible ones such as diatoms. The definiteness of form is a character by which many

animals are identified; but plants, too, under normal conditions, develop a very definite form by which species can be identified. While many or most animals respond actively and spontaneously to external stimuli, there are many kinds such as sponges which cannot exhibit a visible response, even to violent disturbances. As a rule, plants, on the other hand, respond slowly to stimuli; but there are many species which are so extremely sensitive to touch that they fold their leaves with almost lightning rapidity when they are disturbed. One of the most remarkable of these is the tropical sensitive plant, *Mimosa*, which folds up so rapidly that it must be anaesthetized before it can be placed in a plant press. The insectivorous plants mentioned elsewhere are further evidences of plant sensitivity. Even the spontaneous movements of the stamens of barberry and mountain laurel (*kalmia*) in response to the slight disturbances produced by alighting insects (see Plants), and the opening and closing of flowers are sufficient to eliminate active response as a distinguishing feature of animals alone.

In higher forms of living things there is a distinct organogeny; in animals these organs are developed internally, while in plants they are added externally. But the lower forms of plants and animals do not have organs. The cells of higher plants have walls of cellulose which is a feature not present in any animals. But the lower plants lack this type of cell wall, and therefore this cannot be considered as a distinctive feature. Both plants and animals are composed of protoplasm, and both utilize the products of cellular metabolism for skeletal purposes. Both eliminate water vapor, the animals by evaporation from the body surface and in the breath. In plants the water is given off by transpiration through the stomata on the leaves. The respiration of plants and animals is the same, both requiring oxygen and both eliminating carbon dioxide. In plants, however, the breathing takes place mostly at night. Both plants and animals reproduce by sexual and asexual methods.

Thus when the vital processes of the two kinds of living organisms are critically compared, we see that with respect to the usual supposed differences, both kinds are fundamentally similar.

However, there is one striking and universal feature by which plants are distinctly contrasted with animals. It is in their manner of nutrition. All green plants are capable of converting inorganic materials into organic substance by photosynthesis (see Plants),

which animals cannot do. The latter must receive their organic materials directly or indirectly from plants. The plants lacking chlorophyll (saprophytes) obtain their substance directly from organic material manufactured by green plants. It is pointed out in the discussion of plants that there are many organisms which, as yet, cannot definitely be identified as plants or animals. A vast interdependence exists between animals and plants and they are often found intimately associated. Striking resemblances and

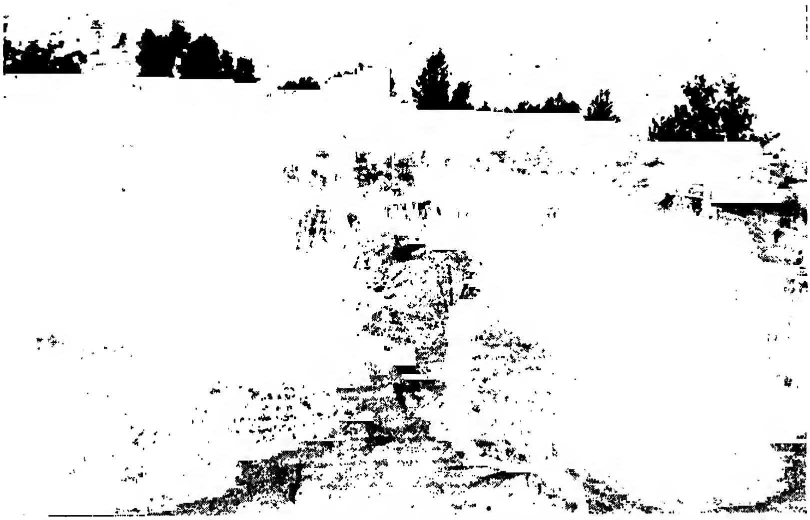


Fig. 2. Sand dunes: here dwells a unique association of plants and animals.

similarities between the two groups of living organisms exist, and the mutual effects of one upon the other can be observed everywhere.

The Phases of Biological Study

The study of biology includes many organisms. In order to understand a group thoroughly, the professional biologist must confine himself to a certain group or to some special phases of plants or animals.

Biology consists of two principal divisions: *Botany*, which is the study of plants; and *Zoölogy*, which is the study of animals. In both of these divisions there are general and specific phases of an extensive nature. Consequently biology is divided into the several subsciences listed here. Each subscience seeks to gather

a sum-total of one kind of information about plants and animals and to determine and interpret the principles which govern the living substance. The names in parentheses are those attributed to specialists in those fields.

Morphology. The study of the form and structure of organisms. This includes anatomy, which is the study of larger structures; histology, the structural features of tissues; and cytology, which is the study of the minute anatomy of cells. It also includes embryology, which is devoted to the study of the formation and development of organisms. Every organism, whether simple or complex, is composed of differentiated regions or structures, all of which are involved in the processes concerned with maintenance of life. These structures combined give to the organism its body form. By the body form most living things are identified. However, to interpret the lives of these organisms it is necessary to know just what structures compose their bodies. Since the naturalist is concerned with the organism as a whole, he must also interpret its body form with respect to habits and relationships. (Anatomist, morphologist, histologist, cytologist, embryologist.)

Physiology. The study of the functions of tissues, organs, and cells. It involves adjustments of organisms for respiration, excretion, and environmental response. It also includes color formation, color changes, hibernation, maintenance of temperatures, etc. (Physiologist.)

Ecology. The study of all of the relationships between an organism and its environment. It is really physiology applied to the organism as a whole. It includes habitat selectivity, behavior, structural modification in response to environmental demand, protective coloration, etc. (Ecologist.)

Zoögeography. The geographical distribution of animals. This is also included in ecology. It deals with the distribution of animals over the face of the earth and involves the dissemination of species. (Zoögeographer.)

Taxonomy. The classification of plants and animals for convenience of study and the application of the principles related to differentiation and kinship. It is the systematic arrangement of organisms into groups on the bases of relationships and involves evolutionary development. (Taxonomist or systematist.)

Genetics. Deals with heredity, variation, and related phenomena. The naturalist is deeply interested in the mutations that

occur in animals and their relations to species formation. (Geneticist.)

Palaeontology. The study of the fossil remains of organisms. It deals primarily with organisms of the past and it supplies the clues to the courses of evolution. (Palaeontologist.)

Evolution. This is the study of the gradual changes that have taken place in organisms throughout the ages. It is the interpretation of palaeontological, physiological, genetic, and embryological studies.

It has been suggested that there are very many kinds of organisms and that the biological principles involved in their survival are so numerous that no one person could acquire a comprehensive knowledge of all groups of living things. For this reason, specialization has developed. When a zoölogist or a botanist is ready to specialize, he selects the group in which he is most interested and then he devotes his energies toward the acquisition of all the information he can obtain about his chosen field. In groups which are unusually large (such as the insects) the specialist chooses an order, family, or even a subfamily for his life's work. Thus an entomologist may be proficient only in the knowledge of a single group of insects such as bees, ants, flies, bugs, or beetles.

The special studies have names which characterize them, and the students in each field are known by the names of their special fields of study. For example, *Ornithology* is the study of birds, and a student of birds is known as an ornithologist. Likewise the following names indicate each special science dealt with: *Herpetology* (reptiles and amphibians); *Entomology* (insects); *Helminthology* (worms); *Mammalogy* (mammals); *Ichthyology* (fishes); *Conchology* (shelled mollusks); *Protozoölogy* (microörganisms).

The naturalist must be a combination of all these, since he must not only know organisms but must also be able to interpret them in terms of their environment.

The Classification of Organisms

The classification of organisms in a general discussion is primarily for convenience. There are many kinds of living things, distributed over the entire face of the earth. By arranging into groups those organisms having one or more outstanding characters in common, the ready identification of plants and animals is made possible, no matter where they are found. Relationships

are ordinarily determined by comparing the features of one organism with those of others. By comparing relative structures or parts from the standpoint of position, anatomy, and use, homologies are determined; and through homologies, the relationships between and among organisms can be ascertained.

The vertebrate animals, for instance, all possess a supporting internal skeleton which is attached to a spinal column or backbone. All animals possessing this column in either a primitive or specialized state are placed in the vertebrate group or *phylum* (Chordata) which includes cyclostomes, fishes, amphibians, reptiles, birds, and mammals. Closer relationships are determined by comparing structures which are in relative positions among animals within a group.

A comparison of the wing of a bird, the arm of a man, and the front leg of a dog shows that these structures are very similar, part for part. In other words, since they all occupy the same relative position and apparently have a similar origin, they are homologous. However, a comparison of the wing of a bird and the wing of an insect shows that these two organs, while performing the same function, are in no way similar. They are therefore analogous structures, between which there is no relationship whatever. On the other hand, if the stiff, thickened, opaque front wing of a grasshopper is compared with the scaly front wing of a butterfly or with the clear, transparent wing of a bee, the organs are seen to have a similar origin; and they occupy the same relative positions. They are, therefore, homologous; and a relationship between these insects is indicated, even though the relationship may not appear to be as close as between a fly and a bee. The fact that all insects have six legs and three main body regions makes it possible to recognize insects the world over, even though there are vast differences in size, color, and shape among them. Again, the legs and other structures on insects may be greatly modified for various purposes; but they are immediately recognized as homologous structures when insects of all kinds are compared. The legs, for instance, may be long or short or they may be adapted to running, jumping, digging, swimming, or seizing; but they are unmistakably identified as legs. However, a comparison of the insect leg and the leg of another animal such as a bird will reveal no similarities of structure.

Let us consider the subject a little further. It is obvious that

all birds are vertebrates, but they differ so much from other vertebrates by their structural makeup that they are placed together in a smaller unit of classification called a *class*. While the relationships among birds are obvious, there are, nevertheless, astounding differences among them. This is shown by comparing running birds such as the kiwi and ostrich; diving birds such as the loon, penguin, or grebe; and terrestrial, flying birds such as the robin. From the foregoing it is evident that the larger units of classification, the phylum and class, contain a heterogeneous assortment of individuals The presence of a vertebral column in so many animals suggests the necessity of separating these animals into classes. The variety of structural features mentioned above also shows the need for smaller taxonomic units called *orders*. In the orders, the smaller groups of individuals possessing a set of similar characters are included. The birds are grouped together into orders, in which certain structural features of the wing, foot, bill, and other skeletal characters are common to limited groups of birds within the class. For example, most of the woodpeckers have two toes in front and two behind; and the tips of their tail feathers are pointed and stiffened. These characters (and others) distinguish the woodpeckers from the other birds. Hence they are placed in an order of their own. Similarly the foot characters of the perching birds are sufficiently outstanding to place a great many birds such as larks, finches, thrushes, etc., in the same order.

Within the order there are still smaller and more closely related groups called *families* in which are included birds quite similar in makeup. In these the characteristics make the members of families stand out from the rest of the birds in that order. The thrush family (in its broadest sense), for example, includes the robin, bluebird, and thrush, all of which are quite similar in many respects. The young of bluebirds and robins even have the mottled breasts characteristic of adult thrushes. The taxonomist recognizes characters which distinguish some members of a family from others, and these are placed in still more limited groups known as *genera* (singular *genus*); within the genera are the very closely related *species*. The species is the mark of individualism in organisms, and it is not always easy to establish this. The scientific name of an organism is a combination of the genus and species. The generic name is written with a capital, and the species with a small letter.

There are more than three-quarters of a million different animals known to science. By arranging them into groups, all can be organized into smaller units for study; and by using a classification scheme the numerous kinds can be systematically differentiated and the relationships among them ascertained. In the organization of groups on the bases of relationships, the facts of palaeontology (fossil remains), embryology (developmental processes), physiology (blood tests and metabolic processes), anatomy (structural makeup), and ecology (distribution and environmental response) are utilized.

Scientific names; their derivation and importance. In order to make the systematic arrangement of animals universal in its interpretation, the names of the phylum, class, order, family, genus, and species are usually taken from Greek and Latin. As a rule, the name indicates or suggests an outstanding character of the group or individual. Thus the phylum name Arthropoda (Gr. *arthron*—"joint," *pous*—"foot") means jointed feet; and it suggests the nature of the legs of spiders, crustaceans, and insects which are constructed of movable segments. The class name Insecta means "cut in" (Latin *insectum*) and refers to the distinct body regions (head, thorax, and abdomen) of an insect. The order name Orthoptera (Gr. *orthos*—"straight," *pteron*—"wing") means "straight winged"; and it applies to the manner in which grasshoppers, crickets, roaches, and katydids fold their wings when at rest. This is the character which places these insects in the same order. The family names end in "dae," and subfamily names end in "nae."

Scientific names are frequently terrifying to the student, even to some of those who have studied Greek and Latin; but their derivations are interesting; and they are no more foreign in their makeup than such words as automobile, lavallière, ukelele, or psychology. They constitute the language of biology. However, they should be looked upon as a means to an end; and it is not necessary to attempt to learn them all at once. There are two ways in which the student can painlessly acquire the language of science. If he will look up the derivations of the various group and individual names which he encounters and, in so far as possible, compare their meanings with the organisms themselves, he will have a comprehensive understanding of them; and they are not likely to be forgotten. Then, too, continued studies in deter-

mining identities of organisms will impress them upon the memory, especially if their meanings are learned and understood.

As suggested in the discussion of plant names, the name does not always indicate the characters of the individual or the group. Sometimes specific and generic names are derived from persons honored by having organisms named after them. Occasionally animals are named after mythological characters because of having similar habits. Some of these are: Arachne (spiders); Daphne (a crustacean); Hercules and Minos (beetles). As in plants, the name sometimes suggests locality, such as canadensis, africanus, californicus, virginiensis, carolinensis, mexicanus, and pennsylvanicus. Quite frequently the name of a species indicates color, such as *rubrum* (red); *niger* (black); *alba* (white); *cinnamoneus* (cinnamon); or *auratus* (golden); and occasionally it suggests resemblance, as *elephas* (elephant); *serpentes* (serpent); *medusa* (many snakes); *asterias* (star); *lupus* (wolf); and *echinus* (hedgehog).

While it is unnecessary to attempt to learn the scientific names of a host of animals, it must not be assumed that these names are of no importance. A study of the meaning of a small number of names will indicate just how valuable this information really is.

A classified arrangement of native animals. A classification of the animal world, abbreviated to meet the requirements of this text, is given here to assist the student in understanding just how animals are classified and also for the purpose of enabling him to properly place the animals he observes in the field. Except for the local bird fauna, the more common moths, beetles, butterflies, and other insect groups, and the local reptiles and mammals, the classification of field material beyond families should not be attempted in general elementary courses.

The classification listed here includes only those animals which the student is likely to encounter in the field. It is hoped that the list will not only indicate what animals can be expected in the various situations but will also aid in properly placing each animal found within its proper phylum and class. With the orders and families included, one of the most discouraging and most difficult processes of identification will be eliminated; and the student can then go to special works with confidence that he can determine the specific identity of the specimen at hand. He should at least know where to look for the family characters which are most

important. Specific identification of a great number of animals is too technical for a study of this kind. That is work for a specialist. Only those animals which are extremely common need to be identified by species. These are the ones usually pictured or described in so many books that determination is not difficult. After all, with the exception of birds, mammals, and possibly a few insects, the specific identifications, while interesting and worth while, are of no vital value. The interested naturalist will want to learn to know as many species as possible, however. It is splendid to know a jumping mouse when one is seen, for instance; but the particular species of jumping mouse is of value only to the taxonomist who is interested in geographical distribution and other matters of evolutionary value. Likewise the student of field biology needs only to identify a certain type of land mollusk as a snail belonging to a special family without regard to species or subspecies. To attempt the specific identification of all animals in a region would require so much time and so many detailed studies that it would be impossible to develop an acquaintance with nature as a whole.

Persistent field studies will soon suggest what kinds of animals are to be found in certain places and will also indicate what particular kinds of groups inhabit a specialized, local situation. Additional details of classification are included in the discussion of the various animal groups. This list is for reference in field and laboratory studies. It includes only the commonest of representative animals. In some cases well-known groups are mentioned, while in others only individuals are included.

PHYLUM I. PROTOZOA. The one-celled animals which are mostly microscopic, such as ameba, paramecium, and euglena. These are not included in the text.

PHYLUM II. PORIFERA. The sponges. Found chiefly in the ocean. Only one class is represented in fresh water.

CLASS I. DEMOSPONGIAE.

ORDER 1. MONAXIDA.

Family 1. *Spongillidae*—fresh-water sponges. Found in slow streams, springs, and fresh ponds. Minute.

PHYLUM III. COELENTERATA. Jellyfishes, corals, hydra.

CLASS I. HYDROZOA (*hydra*—"a serpent," *zoön*—"animal").

ORDER 1. TUBULARIAE.

Family 1. *Clavidae*—hydra. Usually attached to objects in ponds. Less than one inch. Slender, upright, tubular body with a whorl of eight tentacles around the top, as a rule.

PHYLUM IV. PLATYHELMINTHES (*platy*—"flat"; *helminthos*—"an intestinal worm"). The flatworms.

CLASS I. TURBELLARIA (*turbo*—"I disturb").

ORDER 1. TRICLADIDA.

Family 1. *Planariidae*—fresh-water flatworms (*Planaria*, *Dendrocoelum*, *Phagocata*). Largest species slightly more than one inch. Attached to stones in cool running water.

PHYLUM V. NEMATHELMINTHES (*nema*—"a thread"; *helminthos*—"an intestinal worm").

CLASS I. GORDIACEA.

Family 1. *Gordiidae*. The hair worms or horsehair worms. Long, thread-like worms which almost tie themselves into knots when disturbed. Most round worms are parasitic, although many live in fresh water and in the soil. They are very difficult to classify, and for that reason only the above is included. Frequently found in springs, ponds, and watering troughs.

PHYLUM VI. ANNELIDA (*annellus*—"a little ring"). The segmented worms.

CLASS I. ARCHIANNELLIDA. Primitive marine worms lacking setae and parapodia.

CLASS II. CHAETOPODA (bristle feet).

ORDER 1. OLIGOCHAETA—earthworms, tubifex.

Family 1. *Tubificidae*—tubifex—case-building worms on bottoms of ponds and streams. Small.

Family 2. *Lumbricidae*—earthworms (fishing worms or night crawlers).

ORDER 2. POLYCHAETA (many bristles).

Family 1. *Nereidae*—nereis, the sandworm. In sand on the beach in the intertidal zone. Head well developed.

CLASS III. HIRUDINEA—the leeches—found in bottom trash or attached to objects and animals.

ORDER 1. RHYNCOBDELLIDA.

Family 1. *Ichthyobdellidae*—in fresh and salt water.

Family 2. *Glossiphoniidae*—fresh-water leeches.

ORDER 2. GNATHOBDELLIDAE—fresh-water and terrestrial leeches.

Family 1. *Hirudinidae*—medicinal and other species. Three-toothed jaws (Fig. 25).

Family 2. *Herpobdellidae*—cylindrical—colored. Three muscular ridges in place of jaws.

PHYLUM VII. BRYOZOA (Polyzoa). Moss animals. Colonial. Jelly-like masses of animals attached to submerged and other objects in ponds and slow streams.

CLASS I. ECTOPROCTA.

ORDER 1. PHYLACTOLAEMATA.

Family 1. *Plumatellidae*. *Plumatella*, the commonest fresh-water forms (Fig. 40).

Family 2. *Cristatellidae*. *Cristatella* and *Pectinatella*. Fairly common (Fig. 40).

Family 3. *Paludicellidae*. *Paludicella*.

PHYLUM VIII. ROTIFERA. Wheel animalcules. Mostly small, almost microscopic, aquatic animals with a disc bordered with cilia on the head.

PHYLUM IX. MOLLUSCA (*mollis*—"soft"). Shelled mollusks including snails, slugs, mussels.

CLASS I. AMPHINEURA. Marine mollusks. Chiton—oval, with eight transverse plates. On beaches sometimes.

CLASS II. GASTROPODA. Snails, slugs (see Plates IV and V).

ORDER 1. PULMONATA.

Family 1. *Lymnaeidae*. Common water snails. In ponds and streams.

Family 2. *Physidae*. Common water snails. In ponds and streams.

Family 3. *Planorbidae*. Common water snails. Flattened, coiled shells, in ponds and lakes.

Family 4. *Ancylidae*. Water snails without coiled shell. Limpets. In brooks, creeks, rivers, on stones.

Family 5. *Pupillidae*. Very small land snails. Found among leaves on ground.

Family 6. *Cochlicopidae*. Small snails among dead leaves on ground. Northern.

Family 7. *Valloniidae.* Minute land snails found in dark, damp places. Northern.

Family 8. *Succineidae.* Small snails on land and in water. Distribution general.

Family 9. *Helicidae.* Medium-sized land snails. Distribution general. On ground, logs, trees, stones. Shell often marked. Only one species in northeastern United States. Operculum present.

Family 10. *Endodontidae.* Fairly large land snails. Widely distributed.

Family 11. *Zonitidae.* A large family of large or small land snails found under logs and among leaves.

Family 12. *Strobilopsidae.* Land snails.

Family 13. *Haplotrematidae.* Shell higher than wide, covering entire body. One native species.

Family 14. *Pleuroceridae.* Operculate snails with much elongated shells. The common form in great lakes.

Family 15. *Testacellidae.* An imported, carnivorous snail with rudimentary, ear-shaped shell on posterior end of body. Found in greenhouses and on imported shrubbery. Mostly in the ground. Slug-like.

Family 16. *Limacidae.* Slugs without shells covering body. Mantle with rudimentary shell covering anterior part of body. Logs, under stones, on trees, and in gardens.

Family 17. *Philomycidae.* Slugs without rudimentary shell. Mantle covering entire body. Trees, shrubs, and on ground. Grayish.

Class III. Pelecypoda (hatchet foot) (Lamellibranchiata). Bivalve mollusks with hatchet-shaped foot for locomotion (see Fig. 47 and Plate VI).

ORDER 1. EULAMELLIBRANCHIATA.

Family 1. *Unionidae.* Bivalvular fresh-water mussels or clams. Found in lakes, rivers, and creeks.

Family 2. *Margaritiidae.* Fresh-water mussels. Shell large, elongated. Rivers.

Family 3. *Cyrenidae.* Very small mussels, th[illegible]y in color. In ponds.

Family 4. *Sphaeriidae.* Finger-nail clams in ponds and lakes. These are most common in northern waters.

CLASS IV. SCAPHOPODA (boot foot). Marine worm. Tooth shells. These are elongated, thin-bodied mollusks that live in tooth-shaped cells.

Family 1. *Dentaliidae.* The tooth shells occasionally found on the beach.

CLASS V. CEPHALOPODA (head foot). Squids, octopi. Body somewhat cylindrical, bilaterally symmetrical. Distinct head with large eyes, a mouth, and a whorl of tentacles around the mouth. A rudimentary shell is present in a few forms.

Family 1. *Nautilidae.* The chambered nautilus. On Pacific coast only. A well-built, chambered shell.

Family 2. *Sepiidae.* The cuttle fish. Not in America.

Family 3. *Sepiolidae.* Squid-like animals with short bodies and prominent heads.

Family 4. *Loliginidae.* Our native squid, Loligo (Plate III, Fig. 8).

Family 5. *Argonautidae.* The Argonaut. An octopus-like animal that lives in a thin, spiral shell without the septa that characterize the nautilus.

Family 6. *Octopodidae.* The octopus or devil fish. Atlantic coast species with body four inches long. Arms or tentacles five inches (Plate III, Fig. 6).

PHYLUM X. ARTHROPODA (*arthron*—"joint"; *pous*—"foot"). Jointed-legged animals such as crustaceans, spiders, myriapods, and insects. The largest animal group in the world.

CLASS I. CRUSTACEA. Crayfish, sowbug, bender, daphnia, lobster, shrimp, barnacles, and crabs.

ORDER 1. OSTRACODA (oar feet). Small fresh-water crustaceans with exoskeleton in two halves like bivalve. Roundish. Size of pinhead. Common in ponds.

Family 1. *Cypridae.* Cypris (Fig. 26).

ORDER 2. COPEPODA. Body elongated, tapering behind. Abdomen segmented, composed of 15 segments. Minute.

Family 1. *Centropagidae.* Diaptomus. Fresh-water and salt-water copepods.

Family 2. *Cyclopidae.* Cyclops. Fresh water. Abundant everywhere in ponds and lakes. Frequently in aquaria (Fig. 26).

ORDER 3. CLADOCERA. Water fleas. Body short and compact. No visible segmentation and enclosed in a bivalve carapace. Four to six pairs of thoracic appendages. Second pair of antennae very large. Numerous families. Common (Fig. 26).

Family 1. *Daphnidae.* Daphnia. Often sold in fish supply stores for feeding small aquarium fishes. Common everywhere in ponds and lakes.

Family 2. *Leptodoridae.* Leptodora. The largest cladoceran. In great lakes and other fresh water. Comes to surface only at night.

ORDER 4. PHYLLOPODA (leaf feet). The fresh-water shrimps. The thoracic appendages are leaf-like gills. Swim on back.

Family 1. *Branchipodidae.* The fairy shrimp. Common in fresh water among water plants.

Family 2. *Limnadiidae.* Body thick, enclosed in oval, laterally compressed carapace. Second antennae with 16 segments. Along shore among plants in fresh water. Widely distributed.

ORDER 5. AMPHIPODA (double feet). Benders or scuds. Body elongated, laterally compressed. First two pairs of thoracic appendages large and jaw-like for taking food. Swim by bending body.

Family 1. *Orchestiidae. Hyalella.* Common in ponds. Fresh water.

Family 2. *Gammaridae. Gammarus.* Common in ponds and streams (Fig. 26).

ORDER 6. ISOPODA (equal feet). The sowbugs, or pill bugs. Body flattened dorso-ventrally. Oval in land forms; elongate in water forms. Gills on abdominal segments. Appendages similar except first pair and last pair.

Family 1. *Asellidae.* Water sowbugs. Found under stones in streams and among bottom trash in ponds and streams.

Family 2. *Oniscidae.* Land sowbugs or pill bugs. Found extensively in trash, old lumber, and logs. All over America.

Family 3. *Armadillidae.* Land sowbugs found in woods under stones and logs. Everywhere.

Family 4. *Trichoniscidiae.* Small land sowbugs found under moss in woods.

ORDER 7. DECAPODA. The ten-footed crustaceans such as shrimps, crayfishes, crabs, and lobsters. Five pairs of thoracic appendages. First pair chelate, as a rule. Eyes stalked. Two pairs of antennae, only one of which is long.

Family 1. *Palaemonidae.* Fresh-water prawns and shrimps. Found in lakes and large ponds among plants. Many species also marine.

Family 2. *Astacidae.* The crayfishes or crawfishes. Streams, ponds, and springs. Some of them dig wells on land in low regions.

Family 3. *Maiidae.* Hairy crabs or spider crabs. Found on shores and mud flats along Atlantic coast. Usually covered with algae.

Family 4. *Cancridae.* Rock crabs found on New England coast and southward to New Jersey. Edible.

Family 5. *Pilmunidae.* Mud crabs. Found on mud flats along Atlantic coast.

Family 6. *Portunidae.* Edible crabs of commerce in the East.

Family 7. *Ocypodidae.* Land crabs living in burrows above high-tide limit. The fiddler crab with one cheliped longer than the other.

Family 8. *Paguridae.* Hermit crabs. Occasionally found in burrows but more frequently in deserted shells of gastropod mollusks on the beach (Plate II, Fig. 8).

CLASS II. ARACHNIDA. The spiders, daddy-long-legs, horseshoe crabs, mites, ticks, and scorpions.

ORDER 1. XIPHOSURA. King crab or horseshoe crab.

Family 1. *Limuliidae.* Limulus, the common horseshoe crab found on the Atlantic coast beaches (Plate II, Fig. 11).

ORDER 2. *Scorpionida.* The scorpions. Front feet chelate. Poison sting on the tail. Mostly southern and southwestern.

Family 1. *Vejovidae.* Southern and southwestern scorpions. Found on ground, under stones and logs.

Family 2. *Scorpionidae.* Scorpions. Texas to California.

Family 3. *Centruridae.* Texas to California. Found under logs, stones, etc.

ORDER 3. PHALANGIDA. The harvestmen or daddy-long-legs.

Family 1. *Phalangiidae.* Daddy-long-legs or harvestmen found on plants and trunks of trees (Fig. 54).

Family 2. *Nemastomatidae.* Found on plants, tree trunks.

ORDER 4. ARANEIDA (ARANEAE). The true spiders (see Plates VII and VIII).

Family 1. *Aviculariidae.* The tarantulas. Large or medium-sized, hairy, somewhat poisonous. Southern, western, and tropical. Occasionally imported on bananas.

Family 2. *Atypidae.* Tarantulas. Rare.

Family 3. *Hypochilidae.* Southern spiders possessing a cribellum and living in umbrella-shaped webs constructed in dark, rocky cliffs.

Family 4. *Uloboridae.* Orb-weaving spiders with cribellum and calamistrum. They differ from true orb weavers in using a hackled band instead of ordinary viscid thread. Found on low bushes or near the ground and occasionally in buildings. Shady places.

Family 5. *Deinopidae.* Cribellate spiders called ogre-faced spiders. One pair of the eyes is very large. Rare.

Family 6. *Dictynidae.* Most cribellate spiders belong to this family. Webs placed on window sashes, plants, and rocks.

Family 7. *Oecobiidae.* Mostly subtropical and tropical cribellate spiders. Rare.

Family 8. *Filistatidae.* Mostly tropical and subtropical. The house spider of the South. Frequently on the outside margins of window frames. Web with prominent entrance.

Family 9. *Dysderidae.* Six-eyed spiders with four conspicuous spiracles near base of abdomen. Plain thread web built as tubular retreat. Acribellate.

Family 10. *Oonopidae.* Six-eyed spiders with four spiracles. Web plain thread. Very small and rare spiders.

Family 11. *Scytodidae.* Six-eyed spiders with three spiracles. Acribellate. Simple webs under stones and logs.

Family 12. *Drassidae.* Eight-eyed, acribellate spiders. Eyes in two rows. A large family of diverse habits and wide distribution.

Family 13. *Pholcidae.* Medium sized with very long legs. Net webs irregular and constructed in dark places. Common species has elongated abdomen. Often found in cellars.

Family 14. *Theridiidae.* Net-weaving spiders. Comb footed. Most common of house spiders. Build webs in corners of room near the ceiling. A large family including many which cover goldenrods with their webs. Body small. Legs long. Eight-eyed. Body form variable.

Family 15. *Linyphiidae.* Eight-eyed, small, sheet-weaving spiders. Webs among grasses close to ground. Frequently prominently marked. Family large.

Family 16. *Argiopidae.* The true orb weavers. Eight-eyed acribellate spiders. The most spectacular web builders. Webs across open spaces.

Family 17. *Mimetidae.* Not many species. Usually found on cliffs. Eight-eyed. Acribellate.

Family 18. *Thomisidae.* Crab spiders or side runners. Legs extended from sides. Body short and stout. They do not spin webs. Some are predatory. Others are protectively and brilliantly colored and lie in wait within flowers.

Family 19. *Ctenidae.* A few southern representatives. They wander about over plants in search of food. Eyes are in three or four transverse rows. They build no webs.

Family 20. *Clubionidae.* A large family which live in flat, tubular webs or in rolled leaves. Some live on the ground under stones. Eight eyes in two rows.

Family 21. *Agelenidae.* Three-clawed, eight-eyed spiders with sedentary habits. Hind spinnerets long. Webs are funnel-shaped. The common grass spiders.

Family 22. *Pisauridae.* The nursery web spiders. These are large hunting spiders which forage on the ground. Webs are made only for rearing the young. Resemble the wolf spiders, but the females carry the egg sac beneath the body.

Family 23. *Lycosidae.* The large, predatory wolf spiders which hide in crevices and under stones. Some of them burrow and construct a chimney or turret around the entrance of the nest. Egg sac carried on tip of abdomen. Grayish.

Family 24. *Attidae.* The jumping spiders. Medium or small size with short body and stout legs. Tarsi with two claws. Many of them bright colored. Eyes large and conspicuous. Found on sides of weather-beaten buildings and in other exposed spots. No web is constructed.

ORDER 5. MITES AND TICKS. Cephalothorax and abdomen fused into a single segment.

Family 1. *Eriophydidae.* The gall-forming mites.

Family 2. *Demodicidae.* The facial mites. In hair follicles on animals and humans.

Family 3. *Sarcoptidae.* The itch mites or harvest mites.

Family 4. *Analgesidae.* The bird mites.

Family 5. *Tyrogliphidae.* House mites. Transported by insects.

Family 6. *Oribatidae.* The beetle mites. Not parasitic. Found in moss, dead leaves, and on bark. Resemble minute beetles.

Family 7. *Gamasidae.* Scavenger mites. Some species parasitic on beetles, birds, poultry, and on mammals.

Family 8. *Ixodidae.* Large ticks parasitic on vertebrates. The dangerous Texas cattle tick and Rocky Mountain spotted fever tick are included.

Family 9. *Hydrachnidae.* Water mites. Parasitic on water insects.

Family 10. *Bdellidae.* Snout mites found in moss and dead wood. Predaceous mites confined to the Atlantic seaboard.

Family 11. *Trombiidae.* Harvest mites. Parasitic on man.

Family 12. *Rhyncolophidae.* Predatory mites found on ground plants.

Family 13. *Argasidae.* Small ticks parasitic on many animals including chickens and mammals.

Family 14. *Tetranychidae*. Red spiders or red bugs. Serious pests to young evergreens, garden plants, and flowers. Very small.

ORDER 6. TARDIGRADA. Water bears. Minute, almost microscopic water animals found in trash along the shores of ponds and streams and in marshes.

CLASS III. MYRIAPODA. The thousand-legged worms and centipedes. Sometimes split into two classes listed here as orders.

ORDER 1. (subclass) CHILOPODA. The centipedes. With one pair of legs on a segment. Legs attached near ventro-lateral margin. Widely separated. 15 to 173 leg-bearing segments. Antennae long. First pair of legs modified into jaws with poison glands (Fig. 52).

Family 1. *Geophilidae*. Body very long and slender. Antennae composed of 14 segments. 31–173 segments. Blind.

Family 2. *Scolopendridae*. 21–23 segments. Antennae 17–31 segments. Mostly southern.

Family 3. *Lithobiidae*. 15 leg-bearing segments, 9 large, 6 small. Aggregate eyes.

Family 4. *Scutigeridae*. The common skein centipede often found in homes. Body short and composed of 15 segments. Last pair of legs longer than body. Antennae very long. Legs very long.

ORDER 2. DIPLOPODA. Thousand-legged worms or millipedes. Two pairs of legs on each segment, attached near ventral median line. Antennae short. Legs on 7th segment of male, usually copulatory except in *Polyxenidae* (Fig. 51).

Family 1. *Polyzoniidae*. Body elongate, somewhat flattened. Antennae short. 30–100 segments.

Family 2. *Julidae*. Body subcylindrical; hard. 30–70 segments.

Family 3. *Craspedosomidae*. Like *Julidae* but without scent glands. Terminal segment elongated with two slender pupillae.

Family 4. *Polydesmidae*. Flattened species. 19–20 segments. Each segment prolonged on sides to form a wing or flange.

Family 5. *Lysiopetalidae.* Similar to *Julidae.* 60 segments. Length 3.5 cm.; width 2 mm.

Family 6. *Polyxenidae.* Body minute, short, soft. Each segment with tuft of hairs. 11 segments.

CLASS IV. INSECTA. The insects with 6 legs and 3 body divisions. 1 pair compound eyes. 1 pair antennae. Ocelli usually present. Wings present in most forms.

ORDER 1. THYSANURA. Primitive, wingless insects. Eyes aggregate. No metamorphosis. Long antennae; chewing mouth parts. Running insects (Fig. 77).

Family 1. *Lepismatidae.* Fish moths. Found in homes and under stones and logs. Two or three bristle-like, many-jointed, antennae-like appendages on end of abdomen.

Family 2. *Machilidae.* Thysanurans with primitive styli on abdominal segments. Not found in houses. In moss, under logs, and stones.

ORDER 2. COLLEMBOLA. The spring tails and snow fleas. Primitive, wingless insects with chewing mouth parts. Antennae with few segments. Six abdominal segments, the first with ventral adhesive tube. Springing organ on fourth abdominal segment. No metamorphosis. Found in soil, among leaves on ground, under stones and logs.

ORDER 3. ORTHOPTERA. Crickets, katydids, walking-stick, mantis, roaches. Four wings, front pair narrow, thickened. Hind wings membranous, broad, folded like a fan when at rest. Chewing mouth parts. Metamorphosis gradual. Genitalia present on tip of abdomen.

Family 1. *Locustidae* or *Acrididae.* The grasshoppers or true locusts. Tympanum on the sides under the wings. Head and eyes prominent. Antennae not nearly so long as body. Diurnal habits. Hind wings sometimes brightly colored. Hind legs large and adapted for jumping (Plate IX).

Family 2. *Tettigoniidae.* The katydids, long-horned grasshoppers, meadow grasshoppers. Tympana or ears on front legs. Antennae as long or longer

than body. Ovipositor on females sword-shaped. Body often green and less robust than in locusts. Many nocturnal. Hind legs enlarged and elongated (Plate IX).

Family 3. *Gryllidae.* The crickets. Tree crickets, mole crickets. Shorter than other Orthoptera. Dark colored. Antennae long. Ovipositor on cricket long and spear-shaped. No broad hind wings in crickets which are brown or black. Nocturnal. Mole cricket with short wings, light brown color, and hand-like front tarsi for digging (Fig. 79).

Family 4. *Phasmidae.* Walking-stick. Body long, twig-like, wingless. Legs long, stiff for walking. Antennae long and slender. Feed upon foliage.

Family 5. *Mantidae.* Body long, slender, twig-like. Wings present. Front feet enlarged, adapted to seizing. Front legs held in position of supplication. Head wide, eyes prominent. Antennae long and slender. Prothorax and front coxae much elongated (Fig. 83).

Family 6. *Blattidae.* The roaches. Body wide, flat, dark colored (brown or black). Head narrow, eyes not prominent. Legs long, slender, nearly equal in length; adapted to running. Antennae long and slender. Eggs carried in oötheca on end of abdomen in female. Thorax wide and prominent. Legs bristly (Fig. 80).

ORDER 4. DERMAPTERA or EUPLEXOPTERA. The earwigs. Beetle-like insects with flattened bodies. Four wings, the outer or front wings horny, meeting in straight line on middle of back. Hind wings small, ear-shaped. Wings much shorter than abdomen. Pincer-like forceps present on end of abdomen. Mouth parts adapted to chewing. Metamorphosis gradual (Fig. 78).

Family 1. *Forficulidae.* Mostly southern. Under stones and logs. In soil at bases of roots.

ORDER 5. EPHEMERIDA or EPHEMEROPTERA. The May flies. Soft-bodied with four, net-veined, gauzy, triangular wings. Front wings much larger than hind ones. Wings fold vertically above the back when at rest. Front legs long. Two or three many-jointed appendages on end of abdomen. Antennae very short. Mouth parts mandibulate but usually degenerate in adults. Larvae in water, with filamentous gills on sides of abdomen. Metamorphosis gradual with many ecdyses. Adults molt once after emerging from nymphal case.

Family 1. *Ephemeridae.* Larvae in swift water. Flat-bodied with two or three long caudal cerci. Gills on sides of abdomen. Adults nocturnal, on vegetation during day (Fig. 42).

ORDER 6. ODONATA. The dragon flies and damsel flies. Four large, slender, membranous wings with many veins and cells. Body tooth-shaped. Antennae very short bristles. Abdomen long, slender, with genitalia on end. Gradual metamorphosis with numerous ecdyses or molts.

SUBORDER ZYGOPTERA (equal wings). The damsel flies. Much more slender and delicate than dragon flies as a rule. Four wings about the same size and shape. Eyes wide apart, globular, and opaque. Wings held at an angle of about forty-five degrees over the

back when at rest. Larvae have three, leaf-like gills on end of abdomen. Abdomen long and slender (Fig. 32).

SUBORDER ANISOPTERA (unequal wings). The dragon flies. Larger and more robust than damsel flies, as a rule. Eyes large, glassy, and close together, except in Gomphids. Hind wings larger and of different shape than front ones. Wings extended horizontally when at rest. Larvae in water with concealed, rectal gills. Abdomen of larva broad in some species. Lower lip long and extensible; covers face like a mask when not being used (Fig. 75).

Family 1. *Agrionidae.* The larger damsel flies, *Calopteryx* and *Hetaerina.*

Family 2. *Coenagrionidae.* Most damsel flies belong here.

Family 3. *Libellulidae.* Most common dragon flies. Wings often with brown cross bars. Bodies sometimes white and hoary. Nymphs rounded and flattened on underside. Flight not sustained in many species.

Family 4. *Aeschnidae.* The large dragon flies without prominent wing markings. Flight sustained—cruising. Nymphs, long, slender, streamlined, greenish.

ORDER 7. PLECOPTERA. The stone flies. Four wings which fold flat on the back. Front wings narrow, hind wings broad. Antennae long. Mouth parts mandibulate but often reduced. Larvae in water with flattened bodies and two rather stiff appendages on abdomen. Tufted gills on thorax. Legs flattened. Metamorphosis gradual, the larvae crawling on stones and emerging from cases. Adults similar to nymphs (Fig. 42).

Family 1. *Perlidae.* Nymphs. Often with yellowish and black markings.

Family 2. *Pteronarcidae.* Nymphs usually dark, uniformly colored. In cooler streams.

ORDER 8. ISOPTERA. The termites. Ant-like insects with broad abdomens. Lacking the slender peduncle which attaches abdomen to thorax in ants. Bodies soft. Live in great nests of their own construction or within wood. Mouth parts mandibulate, and therefore adapted to chewing. Wings present on kings and queens during mating seasons. Several kinds of individuals in a colony. Metamorphosis gradual.

Family 1. *Termitidae.* Only common family in northern sections (Fig. 82).

ORDER 9. PSOCOPTERA OR CORRODENTIA. The book lice. Tiny, whitish, soft-bodied insects with well-developed head and chewing mouth parts. Four membranous wings usually present. Metamorphosis gradual.

Family 1. *Psocidae.* With wings and found in lichens, moss, and on tree trunks.

Family 2. *Atropidae.* The book lice. Wingless.

ORDER 10. MALLOPHAGA. The biting bird lice. Small, wingless, flattened insects with broad heads and short antennae which are often hidden in grooves on the head. Eyes degenerate. Mouth parts adapted to chewing. Metamorphosis gradual. Found on birds and sometimes on mammals.

Family 1. *Trichodectidae.* All chewing lice found on cattle and dogs.

Family 2. *Philopteridae.* On birds. Includes the head louse on poultry.

Family 3. *Liotheidae.* The large poultry louse.

Family 4. *Gyropidae.* Found on guinea pigs. Single tarsal claw for clinging to hair.

ORDER 11. THYSANOPTERA OR PHYSOPODA. The thrips. The small, elongated, slender-bodied insects with pointed abdomens and swollen feet.

The mouth parts are mandibulate with suctorial modification. Prominent but not long antennae. Compound eyes and ocelli present. Four narrow fringed wings. Less than one-eighth of an inch in total length. Found in flowers. Destructive to fruit and onions.

Family 1. *Thripidae.* The onion thrips, the pear thrips, and the greenhouse thrips. Very active, springing insects.

Family 2. *Phloethripidae.* Often wingless. Larger and less agile than preceding family. Found in galls, flowers, and under the bark of trees.

ORDER 12. HOMOPTERA. The clear-winged bugs such as aphids, scale insects, leaf hoppers, tree hoppers. Four membranous wings nearly the same size and shape. In some species the fore wings are leathery and opaque. Wings do not overlap. Mouth parts adapted to piercing and sucking. Metamorphosis gradual (hemimetabolous). Antennae short and composed of few segments. Mostly small in size, some minute.

Family 1. *Cicadidae.* The cicadas. Large, singing, "seventeen-year locusts." Larvae are whitish grubs in ground.

Family 2. *Cercopidae.* The froghoppers or spittle insects. Often found enclosed with saliva-like material (Fig. 87).

Family 3. *Membracidae.* The tree hoppers. Often grotesque in appearance. Sometimes resemble thorns (Fig. 88).

Family 4. *Cicadellidae* or *Jassidae.* The leaf hoppers. Small, triangular bugs with broad heads. Usually green, although some species are brightly colored.

Family 5. *Fulgoridae.* Diverse in form with prolongated heads and with antennae inserted below the eyes on the sides of the head.

Family 6. *Chermidae* or *Psyllidae*. The jumping plant lice. Broad plant lice with jumping hind legs. Nymphs broad and flat.

Family 7. *Aphididae*. The plant lice or aphids. Small insects usually green, yellowish, or black, with winged males. A pair of wax-secreting tubes on the upper side of the fifth or sixth abdominal segment. Antennae long and highly specialized. Found on the stems and the undersides of leaves.

Family 8. *Coccidae*. The scale insects, or mealy bugs. Very small, often wingless, eyeless, and sometimes legless insects that cover themselves with a waxen coat. The mealy bugs are whitish, cottony lice, usually found on the roots of plants. Numerous species of coccids are common and destructive.

Family 9. *Aleyrodidae*. The white flies. Small, soft-bodied, four-winged, leaf-infesting insects with their bodies covered with a powdery material.

ORDER 13. HEMIPTERA. The true bugs. Four wings, the anterior ones thickened and opaque over the basal half: the distal half membranous, as a rule. Mouth parts consist of a piercing sucking tube of variable length. Antennae with five or fewer segments. Metamorphosis gradual (hemimetabolous). The wings overlap at their tips. Most bugs are odorous (Plate X).

Family 1. *Corixidae*. The water boatmen. Aquatic bugs with flattened bodies, wide heads, and elongated hind legs which are oar-like. Handle carefully. From minute to three-eighths of an inch (Fig. 33).

Family 2. *Notonectidae*. The backswimmers. Aquatic bugs with convex bodies and oar-shaped hind legs. Swim on their backs. Handle carefully. Minute to one-half inch, although usually less (Fig. 33).

Family 3. *Belostomatidae* or *Belostomidae*. The giant water bugs or electric light bugs. Large, broad, formidable-looking bugs with

flattened bodies and legs. One to four inches (Fig. 33).

Family 4. *Hydrobatidae* (*Gerridae* and *Veliidae*). The water striders or skippers. Superficially resemble slender-bodied spiders. Seen on surface of still or slow water, skating with jerky movements over the surface film (Fig. 27).

Family 5. *Nepidae.* The water scorpions. Long, stick-like insects with long, stiff, spindly legs. Front feet adapted to seizing and holding other insects and small fishes. End of abdomen supplied with long, needle-like breathing tubes. Mouth a short, awl-like sucking tube (Fig. 34).

Family 6. *Cimicidae.* The bedbugs. Rounded, flattened, wingless, evil-smelling household pests with winged relatives living in woodlands.

Family 7. *Nabidae.* Small, straight-sided, predatory bugs which feed upon caterpillars and other soft-bodied insects. Length slightly more than a quarter of an inch.

Family 8. *Reduviidae.* The assassin bugs. Fairly large, elongated, predatory bugs with narrow heads and elongated mouth parts. Often "bite." Color variable, from black, brown with markings of red. The abdomen is expanded behind.

Family 9. *Phymatidae.* The ambush bugs. Queer-looking, rough, angular bugs with protective body shapes. They lie in ambush in the heads of flowers and seize spiders and insects (Plate X, Fig. 4).

Family 10. *Miridae* or *Capsidae.* The leaf bugs. The tarnished plant bug (Plate X, Fig. 2).

Family 11. *Tingidae.* The lace bugs. Small, gauzy, lace-like bugs (Fig. 89). Found on undersides of leaves.

Family 12. *Lygaeidae.* The chinch bugs. The milkweed bug and chinch bugs.

Family 13. *Pentatomidae.* The stink bugs. Short, broad, slightly triangular, flattened bugs with evil odors. The harlequin bug (Plate X, Figs. 1 and 7) and numerous others.

Family 14. *Coreidae.* The squash bug family. Resemble the preceding but larger and with antennae inserted higher on the head. Body shape variable.

Family 15. *Neididae.* The stilt bug. Slender body and extremely long legs (Plate X, Fig. 5).

ORDER 14. PARASITA OF ANOPLURA. The blood-sucking lice. Numerous species of degenerate insects including head lice, body lice, and the crab louse of humans. Others are commonly found on lower animals. Wingless, flattened, with eyes usually lacking. Metamorphosis gradual.

ORDER 15. COLEOPTERA. The beetles, which are the most numerous in species of all insects. External skeleton usually horny. Four wings, the outer or front pair tough, opaque, meeting in a straight line on the middle of the back. Form and size variable. Antennae variable. One group, the Rhyncophora, with snouts. Families numerous.

Family 1. *Cicindelidae.* The tiger beetles. Long-legged, running, flying, predatory beetles often with bright green, whitish, bluish, or bronze coloration. About half an inch long. They are mostly seen on the ground or flying at a short distance above it. Mostly seen on sandy beaches. Larvae are found in rather moist sand, their location being revealed by small holes. The adults are active beetles with the thorax broader than the head. The eyes are prominent (Fig. 129).

Family 2. *Carabidae.* The ground beetles. A large family of predaceous beetles that have long, flattened bodies, running legs, and usually a dull coloration, many of them being black or dark brown. Found almost entirely on the ground under stones and other objects. Usually nocturnal. The bombardier beetle, the searcher beetle, and the fiery hunter (Fig. 130, G, F, C).

Family 3. *Dytiscidae.* The predaceous diving beetles. Oval, flattened, aquatic beetles with obscure heads, thread-like antennae, and with hind legs flattened, elongate, and fringed with hair. They may be distinguished from other water beetles by the fact that their hind legs move simultaneously, and they progress by forward darts or leaps on land. They range in size from very small species to the large *Dytiscus*, which is more than an inch in length. The front feet of the males are equipped with cup-like discs for holding to the smooth elytra of females (Fig. 39).

Family 4. *Haliplidae.* The crawling water beetles. Small, oval beetles with pointed ends. Not over 5 mm. long, usually yellowish, marked with obscure black spots. Their movements are crawling.

Family 5. *Hydrophilidae.* The water scavengers. Elongated, elliptical beetles with convex dorsal surfaces. Antennae club-shaped. Hind legs move alternately. Usually black and shining (Fig. 38).

Family 6. *Gyrinidae.* The whirligigs. Flattened, broadly oval beetles which collect in numbers on the surface of the water where they gyrate rapidly, zigzagging or diving when disturbed. Most of them have short, flattened, swimming legs; and nearly all are odorous, some pleasantly so and others noxious. Eyes divided into two distinct lobes (Fig. 28).

Family 7. *Platypsyllidae.* The beaver parasite. This is the only adult parasitic beetle.

Family 8. *Silphidae.* The carrion beetles. Two genera, *Silpha* being broad and flat with brownish elytra and a yellowish rounded prothorax which is greatly expanded. The burying beetle or sexton beetle, *Necrophorus*, is narrower, stout, with orange spots. Both are attracted to carrion of all kinds (Fig. 130, A–E).

Family 9. *Staphylinidae.* The rove beetles. Easily identified by long, narrow bodies and greatly shortened wing covers. Numerous species, attracted to carrion and excrement (Fig. 130, D).

Family 10. *Lampyridae.* The fireflies. Soft-bodied beetles with antennae composed of 11 segments. The "lightning bugs."

Family 11. *Histeridae.* Small, short, black, rounded beetles that appear to have no heads. Found in carrion and excrement.

Family 12. *Cantharidae.* The soldier beetles. Soft-bodied, slender beetles represented by the yellowish beetles having the posterior half of the wing covers black. Found in great numbers on flowers in late summer, usually in copulation.

Family 13. *Meloidae.* The blister beetles. Represented by the black goldenrod beetles (*Epicauta*) and the short-winged *Meloe.* The medicinal Cantharadin is obtained from this family (Plate XI, Fig. 7).

Family 14. *Elateridae.* The click beetles or snapping beetles. The thorax is broad, and the head is small and inserted in the thorax. The abdomen tapers posteriorly. Larvae are wireworms. The eyed elater (Plate XII, Fig. 3; Plate XIII, Figs. 3–5).

Family 15. *Buprestidae.* The metallic wood borers. Similar to click beetles in form but all are metallic. The apple tree borer (Plate XII, Fig. 10).

Family 16. *Dermestidae.* The larder or skin beetles. Household pests including carpet beetles (Plate XIII, Fig. 11).

Family 17. *Cucujidae.* The saw-tooth beetles. Very flat, with margin of thorax usually toothed. Found under bark, usually red. The saw-toothed grain beetle (Fig. 131).

Family 18. *Erotylidae.* Wood-boring or stem-boring, greatly convex beetles usually marked with red and black in dull bands across elytra.

Family 19. *Coccinellidae.* The lady bugs (Plate XIII, Fig. 9).

Family 20. *Tenebrionidae.* The darkling beetles. Often found in flour and cereals. Also on tree trunks at night. Numerous species of different habits. Variable in form. Boletotherus and Tenebrio (Fig. 135).

Family 21. *Scarabaeidae.* The scarabs. Tumble bugs (Fig. 134), *Pelidnota* (Plate XII, Fig. 2), June beetle (Fig. 76), and numerous others.

Family 22. *Lucanidae.* The stag beetles. Flattened, brownish beetles with prominent jaws, especially in males. *Lucanus* (Fig. 127).

Family 23. *Passalidae.* *Passalus* (Plate XII, Fig. 11).

Family 24. *Prionidae.* The large, long-horned beetles including *Prionus* (Plate XII, Fig. 14) and *Parandra* (Plate XI, Fig. 3).

Family 25. *Cerambycidae.* The long horns. A large and variable family with long antennae, sometimes much longer than the body. *Cyllene* (Plate XI, Fig. 8), *Saperda* (Plate XI, Fig. 5).

Family 26. *Chrysomelidae.* The flower beetles (Plate XIII). The potato beetle (Fig. 4), tortoise beetle (Fig. 7), asparagus beetle (Fig. 8), spotted cucumber beetle (Plate XII, Fig. 1), and numerous others.

Rhyncophora, or snout beetles. A suborder of Coleoptera including the weevils, such as the chestnut curculio (*Curculionidae*) (Fig. 133), the engraver beetle (*Scolytidae*), and numerous others representing many families.

There are numerous other beetle families in both the Coleoptera and the Rhyncophora. A description of the families is impossible here. The student is referred to Lutz, *Field Book of Insects;* Blatchley, *Coleoptera of Indiana;* and Comstock, *Introduction to Entomology.* Other works are appended to this chapter.

ORDER 16. HYMENOPTERA (membranous wings). Bees, ants, wasps. This group includes the honey bee, bumble bee, and many other familiar insects; but it also has in it a great many lesser-known forms which range in size from very minute wasps which parasitize the eggs of plant lice to the large and conspicuous horntails and ichneumon flies. Most of them have

four membranous wings, the front ones being considerably larger than the hind ones. In flight, the wings are held together by a row of hooks on the anterior margin of the hind wings. The wings have few veins. The ovipositor in the females is frequently modified into a sting, while in others it is conspicuously developed into long, hair-like projections. A few kinds are wingless. Mouth parts are extremely variable. The metamorphosis is complete. The order is large and difficult to classify. The important families are discussed in the text; the commonest families are listed below.

Family (Group) 1. Sawflies (including the families *Xyelidae*, *Pamphiliidae*, *Siricidae*, *Tenthredinidae*, *Cimbicidae*, and *Oryssidae*). These include the more generalized of the Hymenoptera. The wing venation is less reduced than in other Hymenoptera, and the form of the body is less modified. Abdomen is broadly joined to the thorax, the basal segments being similar in form. The ovipositor is well developed and fitted for making incisions in stems and leaves; often saw-like. The larvae of this group are all plant-eaters; and with the exception of the leaf miners are caterpillar-like in form (Fig. 141).

Family 2. *Siricidae* (horntails). Example: *Tremex columba*. Body cylindrical; head large, widened behind the eyes; the anterior tibia each with only one apical spur; last segment with a more or less horn-like projection; ovipositor very long, exserted beyond abdomen, fitted for boring (Fig. 142).

Family 3. *Braconidae*. Includes a large number of parasitic species of small or medium size. Trochanters composed of two joints. Venter is membranous and in dried specimens has a longitudinal fold. Ovipositor often long

and exserted. Differ from the *Ichneumonidae* in that the third discoidal cell (1st M_2) is open. The second and third segments of the abdomen are usually immovably united (Fig. 145).

Family 4. *Ichneumonidae.* Example: *Megarhyssa lunator* (Fig. 143). Include the larger of the parasitic Hymenoptera. Trochanters composed of two joints; first joint of abdomen often elbowed; venter membranous with a longitudinal fold in dried specimens; ovipositor usually long and exserted. Differ from the *Braconidae* in having third discoidal cell closed, and in having all joints of the abdomen freely movable.

Family (Group) 5. Proctotrupids (better-known families are *Pelecinidae*, *Ceraphronidae*, *Platygastridae*, *Scelionidae*, *Diapriidae*, *Belytidae*, and *Heloridae*). Slender, mostly minute insects, nearly all parasitic. Color usually black or brown. Hind wings without an anal lobe. Pronotum extending back to the tegulae. Ovipositor issuing at the tip of abdomen. Wing venation greatly reduced, some forms wingless. Abdomen with a short, cylindrical petiole, the second segment much longer and larger than the others. *Pelecinus* (Fig. 144) largest species.

Family (Group) 6. Cynipids (include the families *Figitidae*, *Cynipidae*, and *Ibaliidae*). Small, often minute, insects, mostly gall-producing. Antennae never elbowed, rarely of more than 16 segments. Pronotum extended to tegulae, or separated only by a membranous area; wings rarely wanting, stigma lacking, at most with five closed cells. Abdomen greatly compressed, dorsal plates usually ex-

tending well down on the sides of the abdomen; basal dorsal segments differing greatly in length in many genera.

Family (Group) 7. Chalcids (commoner families include *Mymaridae, Leucospidae, Chalcididae, Perilampidae, Callimomidae, Eupelmidae, Encyrtidae, Pteromalidae, Elasmidae, Eulophidae, Entedontidae,* and *Tetrastichidae*). Parasitic, mostly minute insects, often with strong metallic reflections. Prothorax does not extend back to tegulae; wing venation greatly reduced, usually of the characteristic type. Ovipositor issuing before the tip of abdomen, usually hidden, but sometimes exserted to great length.

Family 8. *Psammocharidae* (the spider wasps). Mostly medium-sized wasps, a few of large size. Slender in form with long, spiny legs, the hind femora extending to apex of abdomen or beyond, middle tibia with two apical spurs; pronotum extending back on each side to tegulae. The abdomen is sessile. Most of the Psammocharids make their nests in the ground, provisioning them with spiders; a few, however, are mason wasps.

Family 9. *Chrysididae* (the cuckoo wasps). Moderate-sized Hymenoptera, usually of a brilliant metallic green, of coarse sculpture. Abdomen is concave beneath and composed of usually three to four segments, at the most five. Antennae, 13 joints in both sexes. Pronotum does not reach tegulae. Ovipositor tubular, extensile, and many-jointed. No closed cells in hind wings. Parasitic, depositing their eggs in the nests of solitary wasps and bees.

Family 10. *Formicidae* (ants). Social insects, usually excavating their nests in the soil or in decayed wood. Many species establish their colonies under

flat stones and other objects lying on the ground. The colonies are made up of three castes: males, females or queens, and workers (modified females). In some parasitic genera the worker caste is missing. Males and females winged in most species; workers wingless. First segment of abdomen forming a scale or node, second segment also often nodiform, strongly differentiated from rest of abdomen; tegulae absent or much reduced; antennae strikingly elbowed at extremity of scape (Figs. 153, 155, 156, 158).

Family 11. *Mutillidae* (velvet ants). Resemble ants in form of body but lack the erect scale on the pedicel of the abdomen. Body often densely clothed with hair, sometimes ringed or spotted with contrasting colors, usually black and scarlet. Males winged; females wingless and able to sting. Pro-meso and metathorax often fused into a single piece in females.

Family 12. *Eumenidae.* Medium-sized solitary wasps. Differ widely in habits. Some forms burrow in wood, in which cells are partitioned off with mud, and others are mason or potter wasps, forming cells of earth in and on the ground and on twigs. Pronotum extended to tegulae; wings folded longitudinally in repose. Differ from the Vespidae in that the claws are dentate, mandibles are grooved externally; and only two forms, male and female, are present.

Family 13. *Vespidae.* Mostly medium-sized wasps of social habits. Nests composed of gray, paper-like material. In some genera the nests are entirely enclosed except for a small entrance; in other genera the nest consists merely of a paper comb. Pronotum extending back to tegulae; wings folded longitudinally in repose; claws not dentate; mandibles not grooved externally.

Family 14. *Sphecidae* (the thread-waisted wasps). Pronotum collar-shaped, not extending to the tegulae. Petiole of the abdomen extremely long; middle tibia bearing two apical spurs. The sphecids include the mud-daubers, which attach nests of mud to walls and ceilings of buildings, and provision them with spiders. There are also other sphecids which burrow in the sand and provision their nests with caterpillars (Fig. 147).

Family 15. *Bembecidae*. Solitary, smooth-bodied wasps, usually of medium size. Usually black with greenish-yellow bands. Abdomen not petiolate; usually three cubital cells in fore wings; ocelli distorted; antennae inserted close to clypeus; cheeks narrow; labrum large, free, elongate, and pointed; middle tibia armed with only one evident apical spur. Construct burrows in the sand, and provision them with flies. Some species practice progressive provisioning as do birds.

Family 16. *Halictidae*. Small to medium-sized solitary bees. Usually blue to green, sometimes red or yellow, in color, with strong metallic reflections. Radial cell pointed. Usually three cubital cells in fore wings.

Family 17. *Megachilidae* (the leaf-cutter bees). Medium-sized solitary bees, similar in appearances to honey bees. Pollen on ventral side of abdomen except in parasitic forms. Tongue long; only two submarginal cells in fore wings; claws simple, or only with a basal tooth. Most species burrow in dead wood and pithy stems, constructing a nest of either pieces of leaves or of shredded plant fibers. Some species are parasitic, laying eggs in the nests of other leaf-cutters.

Family 18. *Bombidae* (the bumble bees). Large or medium-sized bees of robust form; rather densely covered with hair; usually of yellow and black coloration, although sometimes reddish orange and

black. Flight is noisy. Two genera—*Bombus* and *Psithyrus*. The genus Bombus, composed of social bees, contains a worker caste. The queens found the colonies each year, and the queens of the genus *Bombus* bear pollen baskets on the hind legs as do the workers. Members of the genus *Psithyrus* are distinguished by the absence of pollen baskets. This genus contains no worker castes. Cheeks separating eyes from mandibles longer than the pedicel of the antennae (Fig. 17).

Family 19. *Apidae* (the honey bees). Social bees of medium size. Hind tibia without spurs; marginal cell very long; eyes hairy; only workers possess pollen baskets on hind legs. The single species, *Apis mellifica*, found in this country nests in hollow tree trunks and caverns when not brought under domestication (Fig. 151).

ORDER 17. LEPIDOPTERA (scaly wings). The moths and butterflies. A very large order of insects with diversity of form, color, and habits. Wings covered with fine scales. Metamorphosis complete.

THE MOTHS: (HETEROCERA)

Family 1. *Micropterygidae*. Small, metallic, flower-inhabiting moths. The only moths with mandibulate or chewing mouth parts. Diurnal.

Family 2. *Hepialidae*. The swifts.

Family 3. *Cossidae*. Carpenter moths. Leopard moth (Fig. 97).

Family 4. *Megalopygidae*. Flannel moths.

Family 5. *Eucleidae*. Slug caterpillar moths. Oak slug moth.

Family 6. *Tineidae*. Clothes moths.

Family 7. *Psychidae*. Bagworm moths.

Family 8. *Aegeridae*. Clear-winged moths. Peach borer (Fig. 110).

Family 9. *Tortricidae*. Leaf rollers.

Family 10. *Olethreutidae*. Coddling or apple-worm moth.

Family 11. *Pyralidae*. Snout moths.

Family 12. *Sphingidae*. Sphinx moths or hawk moths (Fig. 107).

Family 13. *Geometridae*. Measuring worms.

Family 14. *Notodontidae*. The prominents.

Family 15. *Lymantriidae*. Tussock moth (Fig. 108, A–C).

Family 16. *Noctuidae*. Cutworms.

Family 17. *Arctiidae.* Tiger moths (Fig. 108 D).
Family 18. *Lasiocampidae.* Tent caterpillars.
Family 19. *Citheroniidae.* Royal moths (Fig. 94).
Family 20. *Saturniidae.* Silkworm moths—*Cecropia*, *Polyphemus*, *Promethea*.

THE BUTTERFLIES: (RHOPALOCERA)

Family 1. *Hesperiidae.* The skippers. Bodies thick. Antennae hooked at their tips (Fig. 115).
Family 2. *Papilionidae.* The swallow tails (Fig. 116).
Family 3. *Pieridae.* White and sulphur butterflies. Cabbage butterfly (Fig. 123).
Family 4. *Nymphalidae.* Four-footed or brush-footed butterflies —monarch, silver spot, wood nymph (Figs. 15, 117, 125, list complete).
Family 5. *Lycaenidae.* Blues, coppers, hairstreaks. Small (Fig. 124).

ORDER 18. DIPTERA (two wings). The flies, mosquitoes, and gnats. Two wings with halteres or balancers on metathorax. Metamorphosis complete.

Family 1. *Tipulidae.* Craneflies. Mosquito-like flies with long legs. Found in wet woods and near water (Fig. 37).
Family 2. *Simuliidae.* Black flies, buffalo gnats. Small, short, thickset flies with large heads. Breed in water (Fig. 41).
Family 3. *Psychodidae.* Moth flies and sand flies.
Family 4. *Chironomidae.* The midge flies. Larvae in water.
Family 5. *Cecidomyiidae.* The gall gnats.
Family 6. *Mycetophilidae.* The fungus gnats.
Family 7. *Culicidae.* The mosquitoes (Fig. 35).
Family 8. *Tabanidae.* The horse flies (Fig. 36).
Family 9. *Stratiomyiidae.* The soldier flies. Larvae in water.
Family 10. *Asilidae.* The robber flies (Fig. 139, I, J, K).
Family 11. *Bombyliidae.* The bee flies (Fig. 137).
Family 12. *Dolichopodidae.* The long-legged flies.
Family 13. *Phoridae.* Humpbacked flies. Small.
Family 14. *Syrphidae.* Flower flies (Fig. 17).
Family 15. *Conopidae.* Thick-headed flies.
Family 16. *Trypetidae.* Fruit flies. Apple maggot.
Family 17. *Drosophilidae.* Pomace flies. Vinegar gnats. Attracted to fruits. Small.
Family 18. *Muscidae.* House flies, stable flies (Fig. 136).

Family 19. *Calliphoridae*. Flesh flies. Large; bluish or grayish (Fig. 138).
Family 20. *Sarcophagidae*. Flesh flies. In carrion.
Family 21. *Tachinidae*. Tachinid flies. Hairy-bodied, predatory flies.
Family 22. *Oestridae*. Botflies, blowflies, warbles.
Family 23. *Hippoboscidae*. Sheep tick, louse flies.
Family 24. *Braulidae*. Bee lice. Parasitic on bees.

ORDER 19. STREPSIPTERA (twisted wing). Beetle-like parasites between abdominal segments of bees and wasps.

ORDER 20. TRICHOPTERA (hairy wings). Caddis flies (Fig. 42, D). Moth-like insects with four hairy, similar wings. Antennae long, slender. Larvae are case builders in ponds and streams. Metamorphosis complete. Adults nocturnal. Found on vegetation along streams during the day. Larval cases shown on Plate I.

Family 1. *Limnophilidae*.
Family 2. *Sericostomatidae*.
Family 3. *Calamoceratidae*.
Family 4. *Leptoceridae*.
Family 5. *Hydropsychidae*.
Family 6. *Polycentropidae*.
Family 7. *Philopotamidae*.
Family 8. *Rhyacophilidae*.
Family 9. *Phryganeidae*.

ORDER 21. NEUROPTERA (nerve wing). Dobson fly, ant-lion. Four finely veined wings. Mouth parts mandibulate. Antennae long. Metamorphosis complete.

Family 1. *Corydalidae*. The dobson fly (Fig. 43).
Family 2. *Sialidae*. The fish fly or alder fly (Fig. 29).
Family 3. *Chrysopidae*. The lace wing (Fig. 68).
Family 4. *Myrmelionidae*. Ant-lion (Fig. 91).

ORDER 22. MECOPTERA (long wing). The scorpion flies. Four long, narrow wings. Head elongated. Mouth parts mandibulate. Larvae caterpillar-like. Metamorphosis complete. Found in shady woods on foliage.

Family 1. *Panorpidae* (scorpion flies) (Fig. 90).

PHYLUM XI. ECHINODERMATA (hedgehog skin). Starfishes, sea urchins, sand dollars, brittle stars,

basket stars, sea cucumbers. Spiny and tough-skinned; radially symmetrical; usually composed of five arms or antimeres radiating from a central disc. No land or fresh-water representatives.

CLASS I. ASTEROIDEA. Starfishes (Plate II, Figs. 1, 2, 7).

CLASS II. OPHIUROIDEA. Brittle stars. With small body disc and long, serpentine arms (Plate II, Fig. 4).

CLASS III. ECHINOIDEA. The sea urchins and sand dollars. Body subglobular, the five antimeres fused together; covered with movable spines.

CLASS IV. HOLOTHUROIDEA. Sea cucumbers with long, cylindrical, or ovoid bodies covered with muscular body wall.

CLASS V. CRINOIDEA. Crinoids or sea lilies (Plate II, Fig. 3).

PHYLUM XII. CHORDATA. All characterized by having a notochord or an articulated backbone. The vertebrates are the ones of most importance here.

CLASS I. CYCLOSTOMATA. Primitive, cold-blooded, fish-like vertebrates without jaws. The lamprey. Common in northern lakes and streams. (Plate XVI).

CLASS II. ELASMOBRANCHII. Sharks and rays.

CLASS III. PISCES. Fishes. Cold-blooded vertebrates with jaws and usually with lateral fins (see Plates XV, XVI, XVII, XVIII, XIX).

ORDER 1. CHONDROSTEI.

Family 1. *Acipenseridae.* Sturgeon. Body covered with bony plates.

ORDER 2. HOLOSTEI.

Family 1. *Amiidae.* The bowfin.

Family 2. *Lepisosteidae.* Gar pike.

ORDER 3. TELEOSTEI. Bony fishes.

Family 1. *Cyprinidae.* Carp, goldfish, minnows.

Family 2. *Catastomidae.* Suckers.

Family 3. *Siluridae.* Catfishes.

Family 4. *Salmonidae.* Salmon, trout.

Family 5. *Esocidae.* Pike.

Family 6. *Anguillidae.* Eel.

Family 7. *Gasterosteidae.* Stickleback.

Family 8. *Syngnathidae.* Sea horse (marine).
Family 9. *Percidae.* Perch, darter, miller's thumb.
Family 10. *Centrarchidae.* Sunfish, bass.

CLASS IV. AMPHIBIA. Frogs, toads, salamanders. Cold-blooded, smooth-skinned vertebrates.

ORDER 1. CAUDATA. Tailed amphibians (see Plate XIV).
Family 1. *Proteidae.* Necturus or mud puppy with purplish, plumose, external gills. Rivers and creeks.
Family 2. *Sirenidae.* The siren. Long, slender, cylindrical body with small front feet. The hind limbs are absent.
Family 3. *Amphiumidae.* The Congo eel. Body long, slender, serpentine; with two pairs of small limbs; one pair of gill openings; without eyelids.
Family 4. *Cryptobranchidae.* Hellbender.
Family 5. *Salamandridae.* *Triturus.*
Family 6. *Ambystomidae.* *Ambystoma,* tiger salamander, marbled salamander.
Family 7. *Plethodontidae.* *Eurycea, Desmognathus.*

ORDER 2. SALIENTA. Frogs and toads. Tailless amphibia; without scales; two pairs of limbs; without external gills or gill openings in adult.
Family 1. *Pelobatidae.* Spade-foot toad.
Family 2. *Bufonidae.* Common toad.
Family 3. *Hylidae.* Tree frogs.
Family 4. *Brevicipitidae.* Narrow-mouthed toads.
Family 5. *Ranidae.* True frogs. Green frog, bullfrog, leopard frog, pickerel frog.

CLASS V. REPTILIA. Turtles, tortoises, crocodiles, alligators, lizards, chameleons, and snakes. Cold-blooded, scaly skinned.

ORDER 1. TESTUDINATA. Turtles and tortoises. Reptiles with body encased in a bony capsule; jaws toothless; quadrate bone immovable; pentadactyl appendages (usually).
Family 1. *Chelydridae.* Snapping turtles. Small plastron; tail long; limbs, neck, and head large, not capable of being withdrawn into shell; hook-beaked snout. *Chelydra* (Fig. 192).
Family 2. *Kinosternidae.* Musk and mud turtles. Eight bones in the plastron. *Kinosternon, Sternotherus* (Fig. 188).

Family 3. *Testudinidae.* Tortoises and most turtles. *Testudo, Emys, Chrysemys* (Fig. 187).

Family 4. *Trionychidae.* Soft-shelled turtles, broadly webbed digits; head and neck retractile. *Trionyx, Amyda* (Fig. 193).

ORDER 2. CROCODILIA. Crocodiles, alligators, and caimans. Procoelous vertebrae; single nostril at end of snout; front feet with five digits; hind with four and traces of a fifth; anus a longitudinal slit.

Family 1. *Crocodilidae.* Crocodiles, alligators, caimans (Fig. 195).

ORDER 3. SQUAMATA. Chameleons, lizards. Horny epidermal scales; vertebrae usually procoelous; quadrate bones movable.

Family 1. *Chamaeleontidae.* Digits in groups of two and three, for grasping. Chameleons.

Family 2. *Iguanidae.* New World lizards. Teeth similar, fastened in a groove. *Anolis, Sceloporus, Phronosoma, Iguana.*

Family 3. *Teiidae.* New World lizards. Tongue long, bifid, retractile; tail long; limbs well developed. *Cnemidophorus.*

Family 4. *Scincidae.* Skink (fence lizard). Tongue scaly; only slightly necked; limbs may be reduced or absent; well-developed bony plates on head and body.

ORDER 4. SERPENTES (Ophidia). Elongate; limbless; anal opening transverse; paired copulatory organs; eyelids immovable; tympanic cavity; urinary bladder and pectoral arch; rami of lower jaw connected by ligament.

Family 1. *Leptotyphlopidae* (*Glauconidae*). Burrowing snakes. Lower jaw toothed; vestiges of hind limbs and pelvis. *Glauconia, Anomalepis.*

Family 2. *Boidae.* Pythons and boas. Usually large; pelvic and hind limb vestiges; ventral scales transversely enlarged; eyes free and functional.

Family 3. *Colubridae.* Harmless and poisonous snakes. Snakes with facial bones movable; both jaws toothed. Garter, water, black, and milk snake (Figs. 176, 180, 181, 183).

Family 4. *Viperidae* (*Crotalidae*). Thick-bodied poisonous snakes with a pair of large perforated fangs. Rattle-

snake, copperhead, and moccasin (Figs. 185–186).

CLASS VI. AVES. The birds. The only animals possessing a coat of feathers. The characters of the orders are listed in the chapter on birds. The orders and families are as follows.

ORDER 1. GAVIIFORMES. Divers. Loons. About lakes.
Family 1. *Gaviidae.* Loons.

ORDER 2. COLYMBIFORMES. Divers. Grebes. Ocean, lakes, and ponds.
Family 1. *Colymbidae.* Grebes.

ORDER 3. PROCELLARIFORMES. Albatrosses and petrels. On ocean.
Family 1. *Diomedeidae.* Albatross.
Family 2. *Hydrobatidae.* Shearwater, petrel.
Family 3. *Oceanitidae.* Stormy petrel.

ORDER 4. PELICANIFORMES. Pouch-billed birds. Lakes, streams, and ocean.
Family 1. *Phaethontidae.* Tropic bird.
Family 2. *Pelicanidae.* Pelican.
Family 3. *Sulidae.* Gannet, booby.
Family 4. *Phalacrocoracidae.* Cormorant.
Family 5. *Anhingidae.* Darter.
Family 6. *Fregatidae.* Man-o'-war bird, frigate bird.

ORDER 5. CICONIIFORMES. Wading birds. Ponds, streams, shores of lakes and ocean.
Family 1. *Ardeidae.* Heron, bittern.
Family 2. *Ciconiidae.* Stork, ibis.
Family 3. *Threskiornithidae.* Spoon bill.
Family 4. *Phoenicopteridae.* Flamingo.

ORDER 6. ANSERIFORMES. Duck-like birds. Ducks, geese, swans.
Family 1. *Anatidae.* Contains all members of the order and includes seven subfamilies. Seen about lakes, ponds, streams.

ORDER 7. FALCONIFORMES. Hawks, eagles, vultures.
Family 1. *Cathartidae.* Turkey buzzard or vulture.
Family 2. *Accipitridae.* Hawks, eagles.
Family 3. *Falconidae.* Falcons.

ORDER 8. GALLIFORMES. Scratching birds.
Family 1. *Tetraonidae.* Ruffed grouse.
Family 2. *Perdicidae.* Bobwhite quail, helmet quail.
Family 3. *Phasianidae.* Ring-neck pheasant.
Family 4. *Meleagridae.* Turkeys.

ORDER 9. GRUIFORMES. The runners. Cranes, rails.
Family 1. *Megalornithidae.* Cranes.

Family 2. *Aramidae.* Limpkin.
Family 3. *Rallidae.* Gallinule, coot, and rail.

ORDER 10. CHARADRIIFORMES. Shore birds.
Family 1. *Charadriidae.* Plovers.
Family 2. *Scolopacidae.* Snipe and sandpipers.
Family 3. *Phalaropodidae.* Phalaropes.
Family 4. *Laridae.* Gulls and terns.
Family 5. *Alcidae.* Auks, murres, and puffins.

ORDER 11. COLUMBIFORMES. Doves and pigeons.
Family 1. *Columbidae.* All doves and pigeons.

ORDER 12. PSITTACIFORMES. Climbing birds with hooked beaks. Tropics and Southern forests.
Family 1. *Psittacidae.* Carolina parakeet (extinct?).

ORDER 13. CUCULIFORMES.
Family 1. *Cuculidae.* Road runner, yellow- and black-billed cuckoos.

ORDER 14. STRIGIFORMES. Birds of prey with hooked bills. Owls. Nocturnal.
Family 1. *Tytonidae.* Barn owl.
Family 2. *Strigidae.* Great-horned owl, screech owl, barred owl, and others.

ORDER 15. CAPRIMULGIFORMES. Nocturnal, pointed-winged birds. Nighthawks and whip-poor-will.
Family 1. *Caprimulgidae.* Nighthawk and whip-poor-will.

ORDER 16. MICROPODIIFORMES. Pointed-winged birds.
Family 1. *Micropodiidae.* Chimney swift.
Family 2. *Trochilidae.* Humming bird.

ORDER 17. CORACIIFORMES. Strong-billed birds.
Family 1. *Alcedinidae.* Kingfisher. Along streams, lakes, and ponds.

ORDER 18. PICIFORMES. Pecking birds, wood-drilling birds. Woodland birds.
Family 1. *Picidae.* Woodpecker, flicker, sapsucker.

ORDER 19. PASSERIFORMES. Perching birds (Plates XXI–XXIII).
Family 1. *Tyrannidae.* Flycatcher. Kingbird.
Family 2. *Alaudidae.* Larks. Horned lark.
Family 3. *Hirudinidae.* Swallows.
Family 4. *Corvidae.* Crows and jays.
Family 5. *Paridae.* Tufted titmouse, chickadee.
Family 6. *Sittidae.* Nuthatch.
Family 7. *Certhiidae.* Brown creeper.
Family 8. *Troglodytidae.* Wrens (house wren, Carolina wren, marsh wren, etc.).

Family 9. *Cinclidae.* The dipper.
Family 10. *Chamaeidae.* The wren-tits (Western).
Family 11. *Mimidae.* Mocking bird. Thrasher.
Family 12. *Turdidae.* Thrush. Bluebird. Robin.
Family 13. *Sylviidae.* Golden-crowned kinglet. Gnat-catchers.
Family 14. *Motacillidae.* Pipits and wagtails.
Family 15. *Bombycillidae.* Cedar waxwing.
Family 16. *Ptilogonatidae.* The silky fly-catchers.
Family 17. *Laniidae.* Shrike or butcher bird.
Family 18. *Sturnidae.* English starling.
Family 19. *Vireonidae.* The vireos.
Family 20. *Coerebidae.* Honey creepers.
Family 21. *Mniotiltidae.* The wood warblers.
Family 22. *Icteridae.* Blackbird, oriole, meadowlark.
Family 23. *Thraupidae.* Scarlet tanager.
Family 24. *Fringillidae.* Sparrows, goldfinch, redbird or cardinal, rose-breasted grosbeak, crossbill.

CLASS VII. MAMMALIA. "Warm-blooded" animals having hair, and which nourish their young with milk. (See Mammals) (Plates XXV–XXVI).

ORDER 1. MARSUPIALIA. Mammals with a marsupium or pouch. Kangaroo, opossum.
Family 1. *Didelphiidae.* The opossum.

ORDER 2. INSECTIVORA. Insect-eating mammals.
Family 1. *Talpidae.* Moles.
Family 2. *Soricidae.* Shrews.

ORDER 3. CHIROPTERA. Winged mammals.
Family 1. *Vespertilionidae.* The common insectivorous bats.
Family 2. *Phyllostomidae.* Vampire or blood-sucking bats. Mostly tropical.

ORDER 4. CARNIVORA. The flesh-eating mammals.
Family 1. *Ursidae.* The brown or cinnamon bear.
Family 2. *Procyonidae.* Raccoon.
Family 3. *Mustelidae.* Weasel, otter, skunk, badger, marten, wolverine, fisher.
Family 4. *Canidae.* Wolf, coyote, red fox, gray fox.
Family 5. *Felidae.* Cougar, lynx, wildcat, jaguar, ocelot.

ORDER 5. RODENTIA. Gnawing animals with long incisors in front. Canines absent.
Family 1. *Muridae.* Old World rats and mice.
Family 2. *Sciuridae.* Squirrels, ground squirrel, chipmunk, woodchuck, gopher, flying squirrel.
Family 3. *Geomyidae.* The pouched gophers or pocket gophers.

Family 4. *Castoridae.* Beaver.
Family 5. *Erethizontidae.* Porcupine or hedgehog.
Family 6. *Zapodidae.* Jumping mice.
Family 7. *Cricetidae.* Native rats and mice. Deer mouse, red-backed mouse, wood rat, meadow mouse, muskrat, etc.

ORDER 6. LAGOMORPHA. Rabbits, hares, pikas.
Family 1. *Ochotonidae.* Pika.
Family 2. *Leporidae.* Pikas, hares, and rabbits.

ORDER 7. SIRENIA. Manatees, sea cows, dugongs.
Family 1. *Trichechidae.* Manatees. Florida—rare.

ORDER 8. CETACEA. Whales, dolphins, porpoises.
Family 1. *Balaenidae.* Right whales.
Family 2. *Rhachianectidae.* Gray whale.
Family 3. *Balaenopteridae.* Sulphur bottom whale, sperm whale.
Family 4. *Kogiidae.* Pigmy sperm whale.
Family 5. *Delphinidae.* Dolphins.

ORDER 9. XENARTHRA (EDENTATA).
Family 1. *Dasypodidae.* Armadillo.

ORDER 10. PINNIPEDIA (frequently included in Carnivora).
Family 1. *Phocidae.* Seals or sea lions.

ORDER 11. ARTIODACTYLA (UNGULATA). Hoofed animals.
Family 1. *Tayassuidae.* Peccaries.
Family 2. *Cervidae.* Deer, moose, elk, caribou.
Family 3. *Antilocapridae.* Pronghorn antelope.
Family 4. *Bovidae.* Goats, sheep, antelope, bison.

BIBLIOGRAPHY

General Nature

Borradaille, L. A., and Potts, F. A., *The Invertebrata.*
Comstock, A. B., *Handbook of Nature Study.* Comstock Pub. Co., 1911.
Downing, E. R., *Field and Laboratory Guide of Biological Nature.* Univ. of Chicago Press, 1918.
——, *Field and Laboratory Guide of Physical Nature Study.* Univ. of Chicago Press, 1920.
——, *A Naturalist in the Great Lakes Region.* Univ. of Chicago Press, 1922.
——, *Our Living World.* Longmans, Green,
Eikenberry, W. L., and Waldron, R. A., *Educational Biology.* Ginn, 1930.
Guyer, M. F., *Animal Biology.* Harper,
Hammerton, J. S., *Wonders of Animal Life.* Waverly Book Co., Ltd.,

Hegner, R. W., *College Zoölogy.*

Hegner, R. W., *Invertebrate Zoölogy.*

——, *Parade of the Animal Kingdom.*

Hodge, C. F., *Nature Study and Life.* Ginn, 1902.

Holmes, S. J., *Studies in Animal Behaviour.* R. G. Badger, 1916.

Howes, P. G., *Backyard Exploration.*

Jackman, W. S., *Nature Study for Grammar Grades.* Macmillan, 1899.

Lydekker, R., *Wild Life of the World.* Fred. Warne and Co., 1915.

Needham, J. G., *The Natural History of the Farm.* Comstock Pub. Co., 1916.

Parker, J. J., and Haswell, W. A., *Textbook of Zoölogy.*

Schmucker, S. C., *The Study of Nature.* Lippincott, 1920.

Williams, S. H., and Jennings, O. E., *Spring: The Naturalist Afield.* Univ. of Pittsburgh

Wood, J. G., *My Backyard Zoo.* Thomas Whittaker, 1888.

NOTE. *The Nature Magazine,* published monthly by the American Nature Association, Washington, D. C., is an excellent periodical for general use. It contains excellent articles and illustrations of trees, flowers, birds, insects, amphibians, reptiles, fishes, and mammals.

CHAPTER II

THE INFLUENCES OF THE ENVIRONMENT

No plant or animal is an organic entity, living for itself and by itself, independent of other organisms inhabiting the same area. It must be remembered that not only is the entire life of an organism, as well as all its activities, affected by the physical and chemical factors in the environment; but its life is made a veritable complex of interrelationships by the presence of a multitude of others of its own and different kinds.

With all of these each organism must compete for sustenance. Against all it must directly or indirectly defend its right to survive. Its status with and toward all other individuals must be rather acutely defined and understood.

The environment is not static; rather, it is an ever-fluctuating factor, and living organisms must be equipped to endure the changes continually taking place in the media in which they live. The only places where conditions remain fairly constant are in large caves and at the bottom of the ocean. There the temperature, light, pressure, and chemical conditions change but little from year to year; and the nature of the environment in these situations is such as to preclude an abundance of living things. The animals that do live there are highly specialized, as a rule. The survival of a species is determined by its capacity for adjusting itself to these changes. Naturally there are limits to the ability of an organism to withstand changes in the environment, and the so-called "limits of adjustment" are characteristic for each species. By limit of adjustment is meant the maximum and minimum of conditions which a species can endure. Some species can withstand wide limits of environmental changes, while others have rather narrow toleration limits. Between these two, there is a condition known as the optimum, which is the ideal, under which condition (or set of conditions) the organism thrives.

While all the activities of animals as well as their behavior and even their physiological processes are affected by the physical and chemical factors of the environment, it is also evident that, in any

association, each individual has some relationships which might be termed sociological relationships with all the other members of the community. While each environmental condition or factor has some effect upon the lives of animals, no activity or response in nature can be attributed to any one factor but rather to combined influences.

The interrelationships between or among animals and between animals and plants are numerous and, at times, enigmatical and complex. The sum-total of these interrelations may be briefly stated as follows:

1. **The interrelationships between animals and their inorganic environment.** These involve adaptations and responses to chemical and physical conditions such as light, temperature, water, chemical substances present, air, gravity, molar agents, and the substratum.

2. **Interrelationships with plants.** These include all of the interdependencies and the beneficial and non-profiting relationships between animals and plants. They involve such considerations as food, shelter, mimicry, parasitic and symbiotic associations, as well as arboreal adaptations.

3. **The interrelationships of animals.** These are many and diverse, and they consist of two classes of relationships:

(a) among animals of the same species,

(b) among animals of different species.

Under (a) such things as courtship, sex attraction, secondary sexual characters, home building, rearing of young, mutual assistance, communication, monogamy, polygamy, and gregarious, colonial, and social habits are included. Under (b) the ecological interpretations include such relationships as commensal, parasitic, symbiotic, and predatory.

The animal in order to survive must seek and find food; it must find or provide a shelter from intolerable factors; it must seek, recognize, and win a mate; it must be equipped to escape from or defend itself against innumerable enemies; it must regulate its activities according to the periodicity of its worst enemies, as well as to those of its food victims; it must endure fluctuations of climate and other environmental conditions, and be equipped to survive irregular periods of fast and plenty; it must be able to distinguish between friends and enemies. To accomplish these ends animals have invaded every realm of nature; and they have exhibited a wide diversity of structural modifications, activities, and selection

and construction of home sites and structures. They devour and are eaten; they have developed marked sexual differences and thousands of other devices for finding, recognizing, and being attracted to each other; they have acquired color patterns, which are, in some measure, of protective value; they have become physiologically and morphologically equipped to withstand extremes of temperature and humidity; they have developed weapons and odors of protection; and many of them have adjusted their lives so that their active cycles coincide with those of their chief food selections, plant and animal; a number of them have become able to hibernate or aestivate during unfavorable periods; others migrate from unfavorable to more nearly favorable regions when environmental conditions approach the minimum of their toleration; and still others have developed metamorphoses and other complex life histories to insure their perpetuation.

It is obvious that a comprehensive discussion of all these things would go beyond the limits of a text of this kind; but nevertheless they should always be kept in mind by the student of nature. Since ecology is the study of all of the environmental relationships of organisms, all of the above-mentioned factors must be considered in order to fully interpret and appreciate the lives of animals. Furthermore, they provide a lifetime program of field observations of a most interesting character.

Environmental Factors

A brief discussion of the physical environmental factors will indicate, in a measure, their effects upon the structure and behavior of animals.

Light. Aside from being a source of energy, light enables animals to explore their environment and to see their enemies, their food, and each other. All animals exhibit some sort of response to light. The response is known as phototropism, and it may be either positive or negative—that is, toward or away from the source of light. The quality, quantity, and intensity of light all effect variations in animal activity; and they determine, to a degree, animal associations and the periodicity of activity of all forms inhabiting a region. Many animals are active only at dawn, retiring with the rise of the sun. Others are most active during the morning hours before noon; and these, too, withdraw to some secluded spot during the period when the sunlight is intense. Many

of these, however, continue to be active on cloudy days. Another contingent of animals is active only during the brightest hours of the day. Sometimes a host of forms that are active in the sunlight will suddenly disappear when storm clouds darken the sky. The migratory locust which travels in hordes a half-mile wide will suddenly descend if a cloud obscures the sun during the flight. Diurnal animals frequently retire during an eclipse of the sun. As night approaches with the setting of the sun, other kinds begin their activities; and at dusk the whip-poor-wills, certain bats, mosquitoes, crickets, ground beetles, snakes, and chimney swifts are to be seen. When the curtain of darkness covers the landscape, and after the diurnal forms have withdrawn from the scene, a new contingent, the "night shift," begins its daily routine. At this time skunks, rabbits, rats, mice, raccoons, opossums, tree crickets, fireflies, May beetles, carrion beetles, moths, May flies, stoneflies, water bugs, spiders, flying squirrels, foxes, weasels, frogs, toads, salamanders, owls, shrews, rattlesnakes, copperhead snakes, and a host of other nocturnal animals hold sway. Thus it is evident that light conditions play an important part in determining the periods of activity of animals.

Many nocturnal animals have eyes that glow when a light is flashed upon them. This indicates that their eyes are specialized for nocturnal vision, and their eyes are equipped with a structure, the tapetum, which is a gristly, reflecting device situated back of the lens. This reflects all available light rays, thus effecting an increased utilization of the light that is present, and therefore doubling the intensity of the stimulus. The color reflected when the animals are "spotted" with a flash at night is usually a mark of identification. The tapetum, or a similar reflecting structure, is present in many kinds of animals including moths, frogs, salamanders, alligators, snakes, cats, dogs, raccoons, opossums, night monkeys, and others.

As a rule nocturnal animals have well-developed senses of smell and hearing, and vision probably does not play so important a part with them as with diurnal species. The nocturnal creatures have developed a supplementary set of processes for locating each other; and such devices as odors, calls, and luminescence are utilized by many species.

In addition to regulating the activities of animals, light has a strong effect upon the physiological processes. It affects metab-

olism, respiration, evaporation, and mating instincts. It also has much to do with color, as is indicated elsewhere.

One important phase of light study that should not be overlooked is that of the morphological structures for perceiving light. That protoplasm itself is sensitive to light is indicated by the negative phototropic responses of ameba and other non-specialized protozoans. The stigma or eye spot of Euglena and the host of other structures, including the eyes of insects and higher animals which are specialized for recording light rays, have been developed primarily because of light. Animals that live in subterranean caverns where there is an absence of light are usually blind. There is also some evidence to show that many animals, notably worms and amphibians, have light receptors distributed over the body in the skin. The animals such as tree frogs and chameleons that have the ability to change their colors are enabled to do so largely by photic stimulation through the eyes. The light received through the eyes affects the isolated pigmented areas in the body covering (chromatophores and melanophores) which move about or contract and expand in response to the light stimulus. The fact that many of these animals can change their colors even when their eyes have been removed indicates the presence of the light receptors. The changes are effected much more slowly, however, in animals which have been blinded; and this also suggests that the usual stimulus is received through the eyes themselves.

Temperature. The seasonal cycle of animal activity in temperate regions is evidence of the effects of temperature on the behavior of animals. Vegetative processes in plants cease when cold weather approaches; and the plants prepare for a long, unfavorable period. The spores lack water which would freeze; the herbaceous plants die above the ground; and in trees the sap descends to the roots after the leaves have increased its concentration by transpiring excess moisture. Many animals also develop heavier coats, migrate, hibernate, or go into seclusion for the winter season. In animals which do none of these, the activities are often considerably reduced.

Most insectivorous birds and several species of bats fly to the Southland in the fall and return with the spring. Snakes, frogs, toads, salamanders, lizards, some insects, groundhogs, red squirrels. raccoons, opossums, skunks, bats, many species of rats and mice, snails, slugs, spiders, centipedes, millipedes, and even bears retire

for the winter in the temperate zone. Many of these really hibernate in a comatose state until summer has returned, while others merely store up food upon which they subsist in their winter retreats. Earthworms, ants, larvae, and other ground-inhabiting animals "dig in" a little deeper to escape the freezing temperatures at the surface of the ground. The animals that do remain active must be equipped with protective coverings to withstand the lowered temperatures of winter.

The poikilotherms, or cold-blooded animals, must escape before the cold renders them helpless, since decreased temperatures lower the metabolic rate. The retirement of many warm-blooded animals (homoiotherms) and the migrations of birds are not necessarily the direct result of lowered temperatures, but the latter are certainly indirect causes. It must not be forgotten that the disappearance of food as the result of cold weather and the inability of many animals to get about in the snow necessitate the withdrawal of many species Those that remain active meet the conditions in various ways. They develop extra hair coats; devices for walking on or through the snow (grouse, snowshoe rabbit); excess layers of insulating fatty tissues; and the ability to live upon fruits, seeds, and insects hiding in the crevices of bark or passing the winter in the egg or pupal stages.

However, the effects of temperature upon the lives of animals are far greater than the mere regulation of activity. Throughout the whole of the animal kingdom we can see remarkable adaptations to temperature and its changes. Animals live on glaciers; in cold and warm seas, ponds, and streams; on hot desert sands; and in hot springs. The limits of adjustment to temperature changes are almost as diverse as animals themselves.

Certain species such as monkeys, lions, sloths, jaguars, leopards, parrots, etc., are confined to warm, tropical regions. Penguins and polar bears are indigenous to polar regions.

Some animals like toads, whales, and pumas range from the arctic circle to the equator. The animals which have a narrow temperature range and which usually require warmth in captivity, are known as stenothermal animals, and those which can tolerate wide changes of temperature are known as eurythermal animals. In every zoo there are animals whose cages must be kept warm and others which are kept cool.

Animals are guarded against temperature changes in many

ways. In forms that winter in the egg, the amount of water in the eggs is reduced to a minimum to prevent freezing; and even the cellular contents are so modified or concentrated that the freezing point is far below that of most other animals. It might be stated that sudden changes are most destructive. Many animals can tolerate vast changes if the changes are slowly applied. The common jellyfish of the Atlantic coast, *Aurelia flavidula,* extends from Cape Cod to the Bahamas. The southern forms can live in the colder waters of the North if the temperature is lowered very slowly, but they die quickly when they are suddenly transferred from the warm water to the cold water.

External coats of fur and feathers on mammals and birds are provided to maintain the normal body temperatures. These change in thickness and density with the seasons. The heavier coats of winter prevent the loss of body heat and insulate the bodies against cold. Sweat glands are present in most warm-blooded animals to regulate the body temperatures by evaporation in hot weather when the surrounding temperatures are higher than the body temperatures. The distribution of sweat glands on the body is quite variable. Humans and many other mammals have them quite generally distributed over the body surface, but in dogs and cats there are very few of these glands on the body. For that reason a dog pants when it gets warm and in that way cools its body by evaporation from the mouth. Panting is more a sign of being warm than a sign of fatigue, as is commonly supposed.

In whales, dolphins, and other aquatic mammals there is no need for sweat glands; hence they are absent in these animals. In whales, for instance, whose external hair coat has been lost as the result of response to an aquatic environment, a layer of blubber has been developed beneath the skin to protect against sudden temperature changes.

Shivering is another safeguard against freezing. Shivering increases muscular action; and this in turn causes an increased metabolism of carbohydrates which are evaluated in terms of caloric energy. Internal chemical processes are responsible for a certain amount of body heat in all animals. Cold lowers the metabolic rate in many kinds. The normal body temperatures of warm-blooded animals is constant, regardless of the season. The average normal temperature of humans is 37° C.; of mammals 39° C.; and of birds 42° C.

Cold-blooded animals, which lack the internal regulating processes, are greatly affected by the surrounding temperatures and therefore must hibernate when the thermometer drops to a dangerous degree. Cold renders them helpless by reducing metabolic rates. The ability of insects to spend the winter in the egg or pupal stages is of great survival value and probably developed partly as a protective and survival device in response to climatic changes. It has already been suggested that many animals store up quantities of food in their homes so that they may survive long periods of cold indoors. The metabolic rate is stimulated by heat, and therefore mating instincts and breeding seasons are largely determined by seasonal temperatures. The development of insect eggs and pupae, and the eggs of all other animals, for that matter, is accelerated or retarded by high and low temperatures. Moths and many other insects spin cocoons about their eggs and pupae to protect them from the cold. The writer has kept the pupae of many species of moths for over two years under refrigeration without their emerging. When the pupae were transferred to incubators, the moths emerged in a very short time.

The effects of temperature on animal life are numerous. We know much more about the effects of heat than we know of the effects of cold. However, temperature regulates breeding seasons, the number of broods, and even the number of offspring. Animals brought from cold climates into warm ones have a greater chance for survival than have those of warm climates when taken into colder regions. This is due to the fact that warmth stimulates mating activities while cold has a tendency to suppress the mating desires. Hibernation, which is a distinct temperature response, is discussed elsewhere in this text.

Water. Water is one of the most important of all environmental factors. It constitutes $\frac{1}{4540}$ of the earth's mass, and it covers more than 72 per cent of the earth's surface. It therefore provides a medium of tremendous volume and expanse, in which countless numbers of animals and plants spend all or a part of their lives. In addition to the great numbers of organisms which make it their permanent home, the water presents an excellent source of food for myriads of land animals which invade it for foraging and which also utilize its security for building their homes. Oceans, lakes, and rivers, with their tributaries, also serve as highways for the dissemi-

FIG. 3. The beach on Lake Erie. The beach is a dumping ground for angry waves.

nation of many species of animals. The utilization of these highways has made it possible for many species to effect a wide distribution. On the other hand, water presents very effective barriers to the migration of numerous other species; and in this way serves to restrict certain species to rather confined areas. Many terrestrial species have had distribution most effectively blocked by water barriers. Sometimes a narrow strip of water of great extensity separates two distinct faunas.

Water is more nearly constant than any other physical condition in the environment, and sudden changes in temperature do not occur in it. For this reason it is possible for marine animals to migrate to distant places. Whales, for example, are found from the arctic to the antarctic. There are, however, variations in the physical and chemical nature of water which determine and alter the associations, both plant and animal, which are to be found in it. It may be warm or cold, salty, fresh, or brackish, with innumerable variations in degrees of these properties. Each set of conditions harbors its own coterie of organisms. A sudden discharge of chemical factory wastes into a stream may kill all or most of the plant and animal life in it.

Water may be standing, or it may be rapidly or slowly flowing. In large bodies of standing water such as large lakes and oceans, there are currents which in themselves are definite strata and in which certain of the water inhabitants are always found.

As an environmental unit, the depth, density, turbidity, dissolved chemical substances, gaseous content, hydrogen ion concentration (acidity and alkalinity), temperature, physical states (solid, liquid, gas), and other properties are of vast importance in considering the relationships between water and organic life. In the great rain forests of South America there is a scarcity of shelled mollusks in the streams. This is explained by the fact that the constant rains have leached the soil. All soluble salts have long since been dissolved and washed away. Consequently the waters lack the mineral salts necessary for constructing shells.

Water has a definite effect upon the temperature of an area, as is shown by studies of world climate. The mild climates of England and Japan are due entirely to the oceanic currents which surround them. Sudden and severe changes do not readily occur near large bodies of water; and the stability of the climate at the seashore stands in pronounced contrast to the changing, continental climate

of inland sections. The seasonal and geographical distribution of water vapor (affecting precipitation and humidity) influences climate and therefore affects the distribution and activities of plants and animals. A comparison of precipitation and humidity on the plant and animal life in tropical regions with the conditions in a desert will indicate the effects of moisture on the abundance, nature, and activities of living things.

From the geographical standpoint, the arid and moist areas of the world determine population and progressive development. Where hot and dry seasons coincide, such as where a wide, low plain is bordered by snow-capped mountains on one side, a desert or steppe formation results. Where there is a moisture and heat combination, forests flourish. Precipitation also has its effects. Rain clears the atmosphere, and hail sometimes seriously injures both plants and animals, while water vapor in the form of clouds prevents or retards the passage of radiant energy from the sun to the earth.

Dew is most essential to many animals, particularly to inhabitants of arid regions. Many desert animals and plants could not survive without it, since it is their only source of moisture, and both the plants and animals of arid regions are modified structurally and physiologically for conserving it and for subsisting on a minimum amount. Some of them even have storage chambers in which immediate excesses are held for later use. Desert flowers are frequently capable of developing their processes beneath the ground to such an extent that when they do receive a little rain or a heavy dew, they bloom as if by magic. Sometimes the flower lives but a few hours; but in the short life span flowers of this type seem to accomplish their ends, and the species continue from generation to generation. The desert plants, as a whole, are remarkably adapted to living under conditions of extreme aridity.

From the physiological standpoint of organisms themselves, water is absolutely necessary for respiration, circulation, excretion, nutrition, and temperature regulation. The bodies of animals are composed of from 40 to 90 per cent water. A physiological constancy of "body water" is maintained, even at the expense of tissues when they are denied water and when the air surrounding them is dehydrated.

Most aquatic animals and plants exhibit a definite set of characters, adapted to floating, swimming, breathing, and resisting

swift currents. The amphibious land animals have their external coverings and their appendages modified for a part-time aquatic existence. But the most important effects of water on land animals are related to humidity. Moisture is essential to insects and other animals which shed their external coverings from time to time and to amphibians which breathe partly through their skins. It is also necessary for hatching from eggs and for emerging from pupal cases. A severe drouth sometimes causes moths and butterflies to emerge with crippled wings, and it sometimes makes it impossible for cicadas and May beetles to emerge from their larval cases. Land crustaceans must have moistened gills for breathing; and these therefore cannot exist where the air is dry. Arthropods have external coverings which prevent a rapid loss of moisture by evaporation through the body surface. In humid regions, such as in tropical rain forests, there is sufficient moisture in the atmosphere to prevent rapid evaporation. Consequently many water animals are able to invade land habitats; and the writer has found leeches, crabs, planarians, and water snails on land. Even fishes are able to migrate overland from one pond to another because the atmosphere is saturated with moisture, and their gills do not dry off. The armored catfish of British Guiana leaves the water and wanders about over the mud flats, even going to the edge of the jungle in search of food. This would not be possible in regions of low humidity.

The effects of humidity upon biological processes are stressed by experiments which show that flour mites develop slowly when the moisture is reduced to 13 per cent, and they die when it is reduced to 12.2 per cent. Vinegar gnats, pomace flies, or fruit flies (*Drosophilidae*) require almost 100 per cent relative humidity, and the pupal periods of cereal moths are lengthened by high humidity, being 17 days at 100 per cent relative humidity and 12 days at 22 per cent. Even the body form and size may be altered by humidity. Silkworms are kept in an atmosphere of high humidity to increase their size and the quantity of thread they produce.

When the moisture decreases, most animals manifest definite responses. Certain protozoans encyst; some of the higher animals aestivate; while others have a reduced metabolic rate; some pond-inhabiting toads, frogs, and fishes in tropical regions form cocoons of mud in which they remain dormant during dry seasons. It seems almost miraculous to walk through a dry jungle far away

from a stream and see ponds formed in depressions by a sudden heavy rain, and then to observe that these ponds have fishes swimming about in them; but the writer has had this experience time and again in the region between the Amazon and Orinoco Rivers.

Soil water is also an important consideration. The water in the soil is of four kinds: (1) gravitational water which reaches the lowest possible level and which is sought for by well-digging crayfishes; (2) free water which lies between the particles of soil and whose freezing point is $-1.5°$ C.; (3) capillary water which is the water absorbed by the soil particles and which freezes at $-4°$ C.; and (4) combined water, which does not freeze. These are all important to animals which live underground; and their presence determines not only the animal species and population numbers, but they also affect the root growth of plants. Tiger beetles will not lay their eggs in soil where a high moisture content is not maintained. Insects are usually found in porous soil in which they can burrow and where they will not drown when heavy rains descend. The porosity of the soil causes the excess water to escape. Earthworms rise when their burrows are flooded, and nearly all ground inhabitants dig deeper in periods of drouth when the soil water passes off at the surface.

Vertical distribution of life in water. In deep lakes and oceans there is a unique distribution of organic life. This distribution is determined by numerous factors including depth, pressure, temperature, and the amount of light. A huge body of water is not a cesspool of living things in which all kinds of organic life live in the same sphere of activity. Each species has its limit of freedom, and it is largely confined to a definite realm by the above-mentioned factors and by the existence of all powerful adversaries which live in the realm next door to it. In other words, there is a definite horizontal and vertical stratification of domains. In these live organisms especially adapted to the conditions which obtain. Many of sense organisms are unable to adjust themselves to wide variations of the environmental conditions; and they are therefore confined to limited ranges, as are terrestrial forms. The pelagic fauna lives close to the surface where there is plenty of light and available oxygen. Others live at varying depths where light and oxygen are less in quantity. Some live at the very bottom where there is a total absence of light and where the pressure is tremen-

dous. Many of the animals in these various strata cannot invade the domains above and below, in which other associations are to be found. The animals at great depths are adapted to high pressures and die when suddenly lifted to the surface. Many of these live entirely upon the descending bodies of animals that die in the upper strata, and many of them have luminous organs to compensate for the absence of light. These deep-water animals live entirely in a horizontal area where the conditions are more or less constant and they cannot migrate vertically to the surface. On the other hand, the surface animals cannot descend to great distances because of the increased pressure and reduced temperature. The majority of animals and plants are found at or near the surface where light and oxygen are abundant. There are very few forms at the bottom of deep, fresh-water lakes. Phantom insect larvae (*Corethra*) and certain species of midge fly larvae (*Chironomidae*) have been found at a depth of 600 feet.

Particular and specific adaptations to aquatic existence are discussed elsewhere.

Air. The air with its life-sustaining oxygen is one of the most vital of environmental factors. As a medium in which organisms live, forage, escape, and travel, the air presents to the student of nature a wonderful opportunity for interesting observations on structural adaptations and other biological phenomena. The air forms an envelope 200 miles deep which encases the earth. It would be impossible for earth-dwelling organisms to survive at great heights because they could not obtain sufficient oxygen in the rarefied atmosphere even at a height of ten miles above the earth's surface.

The air was the last medium to be invaded by animals, and the truly aerial kinds are mostly descendants of arboreal ancestors. All of the aerial forms exhibit pronounced evidences of convergent evolution, which is also discernible in aquatic animals.

In considering air as an environmental factor, there are many phases of its properties and its influence on organic life to be carefully analyzed. These phases include its movement, density, humidity, and chemical makeup, as well as its effect on the diffusion and transmission of light; its elastic properties which are responsible for sound transmission; its influence in equalizing temperature; its molar effects; the part it plays in oxygenating water; and its contribution to the dissemination of plant and

animal species. Added to these should be the general features of animals adapting them to an aerial existence; the modes of aerial locomotion; the production and function of sound; animal flight; the adaptations of fruits and seeds to wind distribution; the breathing mechanisms of plants and animals as well as the modifications of the breathing apparatus in animals that live under water; the constancy of gaseous content and the properties of air at different altitudes. From the above, it is evident that air exerts a powerful influence on living organisms. Some of the phases mentioned here warrant separate discussions, while others are too inclusive or involved for treatment here. However, since all of them are important in the ecological study of animals, it might be well to indicate some of the possibilities of any attempt to determine the ways in which air does affect the form, structure, and behavior of animals. Plants are discussed in another section of this book.

Convection currents are caused by the air becoming warmer at one place than at another. When these currents attain a high velocity, winds are produced. Tornadoes, hurricanes, and typhoons destroy plant and animal life in several ways. The overturning of trees and other plants not only results in their death but in the death or injury of numerous animals and other plants through mechanical injury. Trees that grow on ridges where winds are rather constant have their forms greatly modified because their branches grow in the direction of the air current. Heavy winds produce storms on lakes and oceans, and these frequently deposit water animals high up on the shores, away from the water, where they die. Migrating birds are beaten down, blown up against trees and buildings, or driven off their courses. Sometimes they are blown far out to sea, by heavy winds, where countless numbers of them drown. On the other hand, the upward convection currents from the earth enable the broad-winged birds such as hawks, eagles, and vultures to remain aloft for hours by soaring. Strong winds frequently carry insects and other species of animals far out of their natural ranges; and while many of these are unable to survive in their new environment, they do sometimes thrive in their new locations; and their distribution is expanded.

Encysted protozoans, spores of plants, ballooning spiders, winged and tufted seeds, and the eggs of many animals are disseminated by air currents. Because of its erosive effects, the air

modifies the topography of the earth's surface by shifting sand dunes, wearing away rocks, and moving soil. Frequently a considerable amount of this material remains suspended in the atmosphere to such an extent that it has a lethal effect on plant and animal life. Dust-laden atmosphere frequently impairs the health of animals and plants. This was illustrated by the violent dust storms of midwestern United States recently.

It is well known that in addition to the oxygen-content of air there are also present carbon dioxide and other gases which are inimical to both plants and animals. Fortunately the utilization of carbon dioxide by plants and their release of free oxygen help to keep the normal gaseous content of the atmosphere fairly constant. However, factories, fires, and automobiles contribute sulphur dioxide, carbon monoxide, and other gases which certain forms of life cannot tolerate. Consequently many species of plants and animals are not to be found in industrial districts because they cannot endure these vapors; or are repelled by them.

The action of the winds on the surfaces of large bodies of water produces white-cap waves which cause much air to be dissolved in the water, and thus the water receives sufficient oxygen for the support of the plant and animal life inhabiting it. Waterfalls, ripples, and whirlpools are also responsible for the high oxygen content of many streams. The water in running over rocks becomes aerated.

The density of the air is dependent upon altitude and temperature. Some organisms, including humans, cannot live at high altitudes where the air is rarefied. The temperature has considerable to do with the amount of water vapor the air contains. The more water vapor in the air, the lighter it is. The amount of water vapor in the air or, in other words, its humidity, has much to do with plant and animal life in regions where extremes of conditions occur.

The transmission of sound in air is affected by its humidity and density. Since sound and flight are so extensively utilized by animals, they are separately discussed.

The substratum. The substratum may be considered as the surface of the earth at or near which most animals live. Because of its material nature, the organisms which live on the ground or beneath its surface must be equipped for running about over it and, in many cases, for burrowing into it. The substratum on which

terrestrial animals live may be rocky, sandy, or soft in texture. Parts of it are exposed to the sun and winds and are therefore dry; while other sections, such as the forest floor, may be shaded and moist. Some of the inhabitants of the substratum are permanently confined to it, while many species which normally live on or in the ground are capable of jumping for considerable distances or for making very short flights in order to escape from and confuse pursuers. A few of them can ascend trees for food and to reach a haven of safety. A number of animals are nomadic and roam about seeking food; while there is a host of species which make homes on or below the surface of the ground, and they do not wander far afield. Some of the wandering species make nests only during the breeding season. Some ground species construct traps such as sand pits or webs in which they lie in wait for hapless victims. A few of the terrestrial animals merely utilize logs, chips, plants, leaves, and stones, under which they crawl for protection. These seldom construct homes, although many of them seek crevices, hollow logs, and caves in which to escape pursuers, to spend the winter, or in which to rear their young.

FIG. 4. The western pocket gopher. Note the prominent incisors, characteristic of rodents, and the digging front feet. After a painting by E. T. Seton, courtesy Biol. Surv., U. S. Dept. Agric.

The animals of the substratum consist of two groups: (1) the terrestrial, and (2) the subterranean. Among them are foxes, wolves, coyotes, gophers, ground squirrels, pikas, moles, rabbits, skunks, rats, mice, chipmunks, groundhogs, shrews, bears, deer, weasels, and a host of other mammals throughout the world. Among the lower animals to be found on or in the substratum are millipedes, centipedes, pill bugs (isopods), land crabs, well-digging crayfishes, wolf spiders, grass spiders, and other kinds of arachnids; ground beetles, tiger beetles, tumble bugs or dung beetles, carrion beetles, May beetle and cicada larvae, and a host of other beetle adults and larvae; ants; sphinx moths and some arctiid moths; bugs; cockroaches; crickets, grasshoppers, and mole crickets; collembolans; thysanurans; digger wasps, social wasps, bumble bees; earwigs; larvae and pupae of flies. To these must be added numerous birds such as grouse, quail, wild turkeys, plover, meadow larks, and a great many species which build their nests on the ground and others which come to the substratum to feed

(robins, flickers, starlings, magpies, sparrows, etc.)—also salamanders (including land forms of *Triturus*), toads, grass frogs, snakes, lizards, turtles, round worms, segmented worms, land snails, slugs, and too many others to list here. Some of these remain beneath the surface of the ground all of the time, while others only visit the surface periodically. Some of them are active in the daytime, but there is a large number that go about only at night.

A scrutiny of this terrestrial horde reveals a variety of structural adaptations of a unique character. Combined with these are some interesting behaviorisms, defenses, feeding habits, architecture of nests, as well as friendly and antagonistic relationships and associations.

In the first place, the means of locomotion on the substratum involve creeping, crawling, jumping, running, flipping, and snapping. These methods of moving about require specialized structural processes. Of course, crawling, jumping, and running are effected by legs; but the runners usually have long, slender legs of even length, while the jumpers have large, elongated, well-developed hind legs as a rule. An examination of the legs of deer, foxes, wolf spiders, cockroaches, ground beetles, and the other runners in the list of animals included here will reveal the running type of legs. The earthworm may be considered as a typical creeper. It moves by contracting and extending its body, and the bristle-like setae hold the anterior end of the body on the rough substratum while the posterior end is drawn forward. Many caterpillars have fleshy prolegs on the anterior and posterior ends of their bodies for creeping. The hind legs of the jumpers such as crickets, grasshoppers, and katydids, rabbits, kangaroos, and jumping mice are much longer and stouter than the others. However, the elongated hind legs of the grasshopper and the katydid serve a more useful purpose than jumping. They are used to support the body when the insects are standing on vertical or almost vertical stems of grasses, while the elongated hind legs of the skein centipede serve in the capacity of caudal feelers. By means of these enlarged hind legs some of these animals are able to jump, often to considerable distances. Some of the spiders are also able to jump, and the spring tails (*collembolans*) have a bristle-like spring attached to the underside of the abdomen and extending ventrally forward. By means of this apparatus the collembola can leap for as much as six inches. These tiny, whitish insects are easily observed on the surfaces of still ponds to which they are

often accidentally transported. The long, spindly legs of walking sticks are ambulatory and are not adapted to running or jumping; hence the locomotion is crawling and slow. The locomotion of centipedes and millipedes is also crawling.

The click beetles (*Elateridae*), as has been stated, rub the posterior margin of the prosternum against the anterior margin of the mesosternum by a sudden movement of the head, and this results in a snapping which produces a clicking noise. When the click beetle senses danger, it throws its body by this snapping (Fig. 128). Some fly larvae which the author observed in British Guiana could loop their bodies and then so quickly unbend as to flip their bodies for several inches. The mysterious "Mexican jumping bean" jumps when warmed, and the movement is effected by the looping of a legless moth larva within the seed.

Snails and slugs appear to move about on their "stomachs" by wave-like movements of ventral muscles. Snakes have numerous ribs, and the muscular attachments of these and the ventral scales effect locomotion by wave-like contraction. Many of the birds such as sparrows and robins hop about; while plover, killdeer, blackbirds, quail, pheasants, and numerous others walk about. Some of these birds such as pheasants, road runners, sandpipers, ostriches, etc., can rapidly outrun most of their enemies. The loon is so specialized for an aquatic life that it is almost helpless on land; and it usually cannot take to flight unless it is on the water. Penguins use their flightless, paddle-like wings as legs when they are pressed by their pursuers on land. The sora rail has a spur on each wing to help it run at a greater speed through reeds and rushes. Monkeys usually run on all four legs although they can run on their hind legs for some distances. They use all legs in climbing. The anthropoid apes travel mostly on their hind legs, but they must assist themselves along on the ground by occasionally using their closed fists as front feet. The running mammals may be (1) *digitigrade*, that is, running on their toes as do dogs and cats; (2) *plantigrade* like the bear, which is flatfooted and therefore walks on its sole; or (3) *unguligrade* like the horse. Some of them which are not fast runners have soft pads on their feet so that they may noiselessly approach their victims, while the horse, bison, and zebra, which roam in open country littered with stones, have hoofs for protection. As a rule, the hoofed animals are swift runners; but they make considerable noise in their progress.

The bodies of those animals which crawl under bark chips and stones are usually more flattened than those which do not. A comparison of a cricket and a grasshopper will demonstrate this. It will be seen that the flattened body of the cricket is well adapted to crawling under stones where it is frequently found. The deep, angular body of the grasshopper and the upward-extending joints of the long hind legs would make it almost impossible to live as a cricket does.

The legs of the truly subterranean animals are generally short, and the front feet are usually modified for digging. Long legs would make it necessary for these animals to have large entrances and tunnels, which would be disadvantageous; for not only would their homes be conspicuous, but many large and powerful enemies could pursue them into their dens. The bodies of mammalian and reptilian subterranean dwellers are elongated. This makes it possible for them to have sharp bends in their underground tunnels, and the thick-bodied enemies which might be able to get through the entrances could not get around the sharp curves in their runways. On moles, cicada nymphs, tumble beetles, and mole crickets, particularly, the front feet are vastly different from the middle and hind feet, being broad and spade-like and turned to a convenient angle for digging. Groundhogs, ground squirrels, gophers, and other truly burrowing animals use their claws in digging. Usually the subterranean insects lack long antennae and other structures which would be impedimenta.

In considering the subterranean animals there are really three distinct groups. There are those which dig only for shelter such as chipmunks, groundhogs, bank swallows, snakes (hog-nosed snake), toads, lemmings, meadow mice, gophers, ground squirrels, wasps, spiders, ants, and the like. Then there is a group which digs primarily for food. This includes skunks, armadillos, anteaters, opossums, and raccoons. Another group, which includes worms, termites, insect larvae of many kinds, and moles, digs both for shelter and for food. Dung beetles, sexton beetles (*Necrophorus*), tiger beetles, sphinx moths, digger wasps, and rabbits make burrows only for breeding purposes. For instance, the eggs of dung beetles and sexton beetles are laid on or in material placed in burrows. The sphinx moths pass their pupal periods in the ground and do not spin cocoons. Rabbits make nests in which to conceive their young. Quite a number of insects spend only a

part of their lives in the ground. The animals which have their domiciles underground, such as ants, groundhogs, etc., come to the surface for food; and when the soil is not rich in humus, earthworms come out at night and drag leaves into their burrows. Meadow mice, gophers, ground squirrels, and groundhogs seldom venture far from home because their short legs make it impossible for them to run fast; and if they wander too far, a swift pursuer might overtake them before they could reach the safety of their subterranean homes. The meadow mouse, chipmunk, and groundhog have some interesting habits explained in the discussion of mammals. While foxes, weasels and shrews, most snakes, and many spiders use underground passages, they are not truly subterranean animals. They utilize ready-made excavations as a rule.

The animals which actually construct homes on the substratum include birds, many of which make elaborate nests in which a great variety of materials are used; and which differ greatly in form and structure. Termites sometimes make runways over the surface of the ground, while ants build mounds of sand and débris. Tropical species sometimes construct huge and high nests of earth, chewed material, sticks, and leaves. Some social wasps attach their papier mâché nests under overhanging banks.

The architecture of the nests of animals includes the materials used, the methods of construction, and the external and internal plans of the abodes. It would not be possible to describe a great number of them in detail here, but the types of homes of many animals are described in connection with the discussions of the various animal groups.

The animals of the substratum exhibit many interesting color features, complex life histories, defensive structures, social habits, and "predator and prey" relationships. Many of them such as certain birds, migrate to the Southland during winter; others remain active all year round; and a great number of them hibernate in the ground during unfavorable periods.

Gravity. Gravity is the one unalterable and universal environmental factor. One of its most important effects is the pressure produced by it in water, although atmospheric pressure also has its influence upon the lives of organisms.

Animals that are adapted to particular pressures cannot, as a rule, withstand sudden changes. Deep-sea forms usually die, and

some of them even explode when they are hastily brought to the surface. This is because they have internal pressures which are adapted to maintaining an equilibrium with the external pressure at great depths; and when they are lifted to the surface where the external pressure is considerably less, the condition of equilibrium is destroyed, and the internal pressure kills them. It is suggested elsewhere that oceanic faunas are distinctly stratified by the pressures at different depths, and the organisms inhabiting one stratum cannot invade the strata above and below the one to which they are especially adapted. Aeronauts and deep-sea divers sometimes bleed through the surfaces of their bodies because of the abnormal pressures to which they are suddenly exposed. Some persons become greatly and easily fatigued on high mountains where the atmospheric pressure is considerably less than that to which they are ordinarily exposed. Many people have nose bleed at high altitudes, and everyone breathes much faster because of the rare atmosphere.

Since the pull of gravity greatly affects pressure, diving birds are built on a plan that is most efficient for submerging. Gravity holds animals to the surface of the earth; therefore those animals which rise above the earth such as flying birds must be especially constructed for overcoming the pull of gravity. Hence they are unique in having buoyant bones and feathers, and they must be equipped with propelling apparatus that will keep them aloft. Most of these animals have light but bulky bodies. Thus gravity exerts an influence on the sizes and shapes of animals. To remain aloft, both passively and actively flying animals must have a large surface exposed to the material atmosphere.

Water animals have fatty tissues with myriads of air pockets (blubber); plenty of grease or oily material; gaseous pockets; and extensions of the body such as spines; all of which help to keep them afloat. The shape of the body, such as the bell and helmet shape, is also a physical factor in enabling animals to prevent themselves from sinking. Of course swimming apparatus makes it possible for many animals to vertically migrate in water just as wings enable birds to rise above the land. The dorso-ventral and anterior-posterior symmetry of animals are adaptations to gravitational force. The land and water animals which lack propulsion and floating devices are held to the surface of the earth or to the bottom of the ocean, lake, or pond. Sea anemones,

sponges, starfishes, and numerous other oceanic forms are either sessile or crawl about over the substratum. Plants and numerous land animals are held in contact with the substratum because they lack all structures which would enable them to overcome gravity.

Altitude. Altitude is closely associated with pressure, although temperature also regulates to a degree the altitudinal distribu-

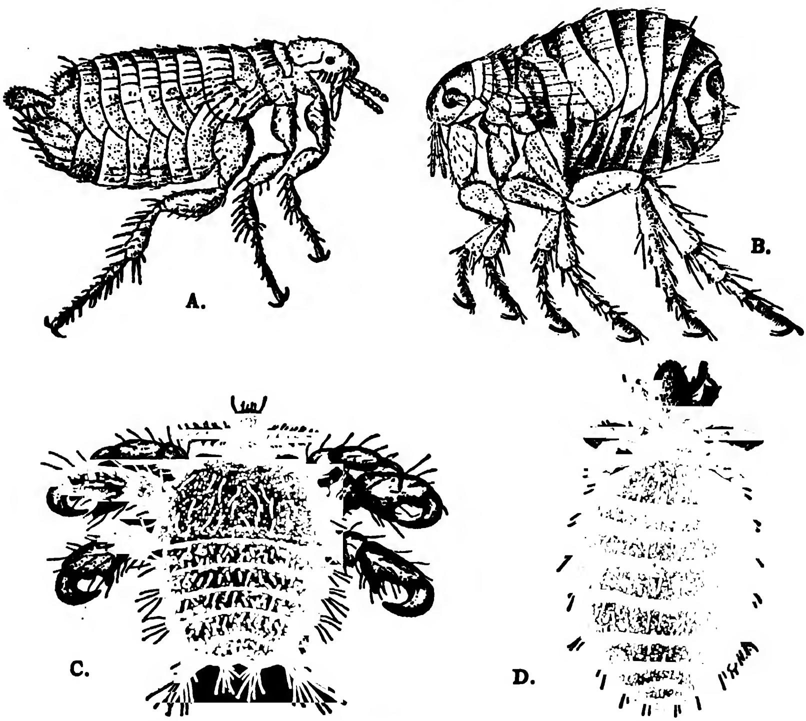


FIG. 5. External parasites. A. Dog flea (*Ctenocephalus canis*); B. Human flea (*Pulex irritans*); C. Human crab louse (*Phtherius inguinalis*); D. Sucking dog louse (*Haematopinus piliferous*). A., B., courtesy U. S. Dept. Agric.; C., D., after Kellogg, *American Insects*, courtesy Henry Holt and Co.

tion of living things. Since many organisms are sensitive to pressure differences, there are those which are confined to highlands while others are typically inhabitants of low regions. One important observation the field student should not overlook is the matter of distribution. When warm regions have high mountains, the mountain tops provide a condition similar to northern latitudes; and on these mountains animals that are characteristically

northern may be found. Since the mountains of North America extend virtually north and south, the mountain ridges provide highways for the southward migration of northern forms, both plant and animal. Therefore the lowland fauna and flora are different from the mountainous fauna and flora. In Pennsylvania, for instance, the mountains which extend southward through the central part of the state harbor animals which are normally characteristic of the Canadian life zone, while the counties on either side of the mountains usually have a more southerly fauna. Certain *Papilio* butterflies (*Parnassius*) are found only above 6000 feet, and they have a discontinuous distribution throughout the world. They are found on the high peaks of the Rockies, Alps, Andes, Himalayas, and the other high mountains. Strangely, they are quite similar in coloration in all of these regions. In fact, they are so similar that anyone can recognize a *Parnassius* no matter whence it came, and only experts can distinguish among them.

The distribution on a mountain side is always unique, with certain species occurring at given altitudes and rather definitely confined to them. The distribution of plants is quite obvious with a progressive distribution of species to the timber line, above which only a few species of small herbaceous plants occur. Temperature which affects growing seasons is probably the principal factor in this distribution. In the cases of many animals the rate of respiration, chemical alterations in the blood, and increased haemoglobin are combined with temperature in effecting the succession of life on a mountain side. The inaccessibility of the high mountains offers a haven of safety for many animals, and this may be partly responsible for altitudinal distribution.

Parasites and Parasitism

Among the many interrelationships of animals, parasitism is probably the most extensive. It has been estimated that more than one-half of all living organisms lead a parasitic existence. Parasitism soon becomes evident to the student of field biology, but too often he overlooks opportunities for some interesting observations on the processes of specialization. As a rule, the parasites on plants are more obvious than those on animals, but even a cursory examination of a beetle, bird, or mammal will reveal some curious creatures that obtain their sustenance to the detriment of others.

A parasitic association is one in which one member of the association lives at the expense of the other. Only one member is a willing member and only one profits. The unwilling member is usually termed the host; and nearly every organism, plant and animal, is a host to one or many parasites.

Parasites may be classed in several ways. They may be temporary or permanent; facultative or obligatory; external or inter-

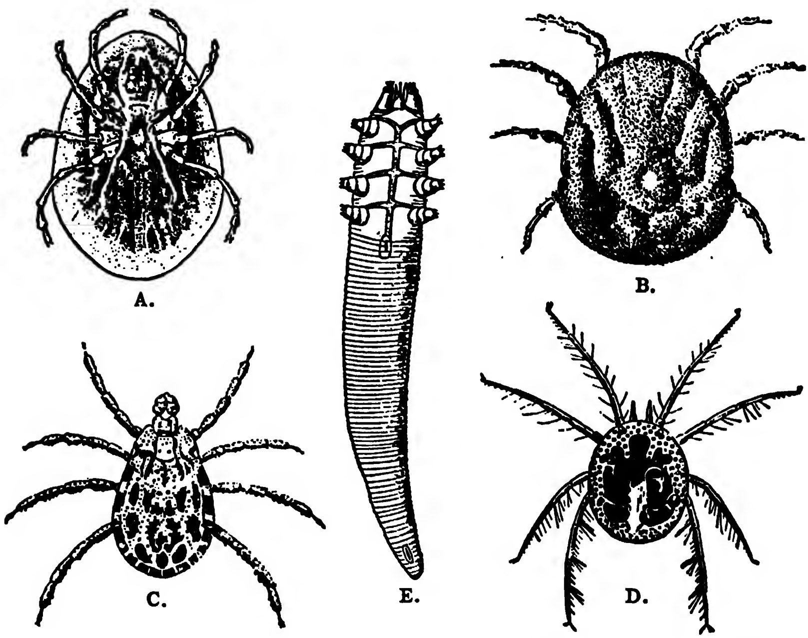


FIG. 6. Ticks and mites. A. and B. Ticks (*Argasidae*); C. Tick (*Lxodidae*); D. Water mite (*Hydrachnidae*); E. Follicle mite (*Demodescidae*). After Brumpt from Hegner, *Invertebrate Zoology*, The Macmillan Company.

nal. Temporary parasites, or partial parasites as they are sometimes called, are those which are parasitic during only a portion of their lives. Ichneumon flies (Fig. 8), warble flies, and braconid wasps (Fig. 9) which lay their eggs in the bodies of other animals (Fig. 7) and which undergo their development there, usually finally emerging as free-living adults, are temporary parasites. Flesh flies, horse flies, fleas (Fig. 5), mites, ticks (Fig. 6), mosquitoes, leeches, larval mussels (Fig. 45), and other animals which spend only a portion of their time on or in the bodies of other animals are, in reality, temporary parasites.

Permanent parasites are those which usually do not have a free-living stage. These depend upon one or more hosts during their entire lives. Most of this type are found among the lower groups of animals, notably the worms.

Facultative parasites are those which may change hosts or select different hosts for obtaining their sustenance. Many of these are capable of living independently if occasion demands.

FIG. 7. Cocoons of the parasitic wasp, *Apanteles congregatus* (*Braconidae*) on a tobacco sphinx moth caterpillar. From U. S. Dept. Agric., Circ. 346.

Obligatory or compulsory parasites are those which are more or less specialized for one kind of host animal although some of them may have a succession of host animals in their different stages of development. Obligatory parasites cannot live a free life at any stage. The liver fluke, for instance, requires a snail and a vertebrate, usually a sheep, to complete its life history and from which to secure a livelihood in all of its stages. Many tapeworms have intermediate or alternate hosts in addition to their final host. The intermediate hosts of some tapeworms which infest higher animals include insects, fishes, and crustaceans. The liver fluke, tapeworms, and many fly larvae are internal parasites.

External parasites are those which usually command the attention of the naturalist because he finds so many parasites on the specimens which he collects. Every grasshopper and almost every beetle and other insect is infested with tiny, red mites. They are usually under the wings of grasshoppers, but they may be found all over the body of the beetle.

Between the abdominal segments of wasps there occasionally occurs a single, curious parasite known as *strepsiptera* which bears a superficial resemblance to a small beetle. On birds there are biting lice (*Mallophaga*) and mites. Bats sometimes are infested

with mites, lice, or hippoboscid flies. The sheep tick (*Melophagus ovinus*—DIPTERA) which is sometimes injurious to the wool on a sheep is a fly, although it does resemble a tick. There are also lice, mites, and ticks on the bodies of sheep; and the botfly lays its eggs in the nostrils. The larvae sometimes enter the brain and produce the well-known condition called "gid" or "staggers" in sheep.

Fleas are found on dogs, cats, rats, rabbits, and squirrels; and these animals also have lice, mites, and ticks occasionally. The sticktight flea causes considerable damage to domestic poultry. It is usually on the head around the eyes. The beaver has an unusual beetle parasite (*Platypsyllus castoris*) which is thought to be the only parasitic beetle in the world. Other mammals also have lice, mites, ticks, and fleas quite frequently. Humans have head lice (*Pediculus capitis*), body lice (*Pediculus corporis*), and crab lice (*Phthirius pubis*) (Fig. 5). They are also susceptible to fleas, leeches, mosquitoes, flies, mites, and ticks. Harvest mites, itch mites, chiggoes or chiggers, and the little red mite (*bête rouge*) which burrows beneath the skin are common, irritating parasites on human beings. The follicle mites (*Demodex folliculorum*) which live in the hair follicles are also common, especially in the region of the nose. Of course there are numerous internal parasites as well.

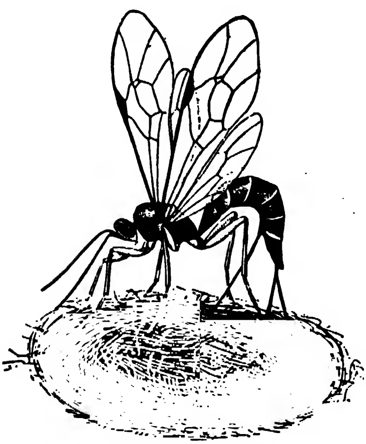


FIG. 8. An ichneumon wasp laying eggs in the cocoon of the apple tent caterpillar. Courtesy Bur. Ent., U. S. Dept. Agric.

The botflies or warble flies (*Oestridae*) comprise those which lay eggs on the hairs of horses and cattle. The eggs are sometimes licked off and pass into the oesophagus where they hatch. The larvae finally reach the subcutaneous tissue on the back, forming small lumps or tumors which are often seen on these animals. When larval development is completed, they leave the body through openings which they make in the hide. The emerging of these insects reduces the value of the skin for commercial purposes.

The fishes have "lice" on their bodies (carp louse) and other copepod (Crustacea) parasites on their gills. They also have larval mussels (glochidia) on their gills and body surface (Fig. 46). The lake and stream fishes may also have lampreys attached to them; and leeches are common parasites on many species.

Leeches, lampreys, the biting flies, and mosquitoes may be considered as facultative, temporary ectoparasites. Snakes and lizards frequently have mites between the scales, particularly in the region of the head. Toads often have wood ticks on their bodies, usually attached to their hind legs.

The smaller ectoparasites can be found by examining the hair, feathers, and scales of birds, mammals, and reptiles with a hand lens. An orange stick makes a good collecting instrument. Most of the parasites are too small to be handled with forceps; and by moistening the end of the orange stick, the small parasites can be picked up. They should all be killed in hot water and then transferred to a suitable preserving fluid. They can be examined microscopically by placing them on glass slides. The remarkable modifications of the body shape, legs, and mouth parts of these parasites are well worth observing. The extensity of parasitism and the adaptive features of the parasites themselves, together with the fact that no other kinds of organisms are so intimately connected with the lives of all plants and animals including humans, certainly make the study of them well worth inclusion in every general course in biology. The field aspects of parasitism should not be overlooked by the student of natural history. The effects of parasites on the lives of the organisms he studies are diverse and well worth knowing. As a rule, parasites do not kill their hosts. For them to do so would remove their source of livelihood. However, they weaken their hosts and make them susceptible to diseases and other conditions which often result in death. The behavior of the host animal is usually affected by a serious infestation of parasites. In recent years, the backward child or the restless, disturbing youngster in school is no longer placed on a dunce stool or thrashed for his delinquencies. He is often the victim of a tapeworm which is sapping his vitality and making him mentally and physically lethargic. Or if he is the fidgety type, he may have head lice, body lice, or some other irritating kind of parasite which is responsible for his restlessness. Parasitic infestation when severe or extended, sometimes produces sterility

or decreased fecundity. It may affect the colors of animals, and it has undoubtedly caused the total extinction of numerous species of organisms.

The life histories of parasites, particularly those which affect humans, and the possible sources of infestation such as through infected pork (*Trichina*) and other meats, fish (*Bothriocephalus*), meal worms (lepidopterous and beetle larvae), fleas (*Dipilydium caninum*), dirty hands (eggs of various kinds of tapeworms), unsanitary living quarters (fleas, lice, ringworms), improper disposal of wastes (hookworm), and a host of others should also be a part of the study of nature.

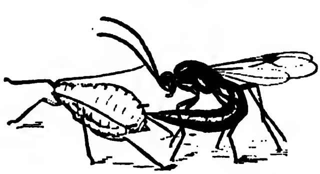


Fig. 9. A braconid wasp (*Lysiphlebus testaceipes*) depositing an egg in an aphid. Courtesy Bur. Ent., U. S. Dept. Agric.

After all, meat inspection and refrigeration, pure food laws, mosquito control, sanitary sewage disposal, sanitary food marketing, pasteurization of milk, hygienic housing projects, tuberculin testing of dairy herds, government quarantines of all kinds, government control over the manufacture and sale of bedding materials, and a great many other important processes are designed to guard the person and effects of human beings against various parasitic organisms.

There are also hyperparasites which are parasitic upon parasites. In fact the tendency of all living organisms to get something for nothing has resulted in an endless chain of responsibility.

Many plants have also developed parasitic habits, and among our common forms there are numerous species which obtain their sustenance from others. The epiphytic mistletoe and dodder; rusts of many kinds such as wheat rust; blights such as the chestnut blight and the white pine blister disease; disease-producing bacilli such as those of typhoid, diphtheria, and tuberculosis; ringworm; and numerous others are true parasitic plants.

While numerous animals such as mites, bugs, plant lice, beetles, and myriads of others are parasitic on plants, the animals themselves are susceptible to fungus diseases which are often fatal.

Parasitism always implies degeneracy. It is invariably accompanied by the loss of processes such as locomotor ability, by alterations of structures, by degeneration of the sensory apparatus, and usually by a specialization of alimentary processes. It illustrates the highest degree of specialization, and it demonstrates

the dangers of overspecialization as well. The biology of parasitism should be a warning to humans who would likewise degenerate through living at the expense of others. Every Naturalist and Sociologist should be familiar with the principles of parasitism.

Symbiosis

Symbiosis may be defined as "the living together of different species for mutual benefit." There are usually only two species concerned although it sometimes happens that several species live amicably together, and their activities are mutually beneficial. The members of the association are called symbionts.

A striking example of symbiosis and one which can be observed almost anywhere during the warmer months is the relation between ants and aphids or plant lice. You have probably noticed ants scurrying about, gently carrying plant lice which they transport to the species of plant to which the aphid is partial. In fact, the ants may gath.. plant lice from your neighbor's garden and place them on the golden glow in your own yard. The ants nurture several species of aphids, carefully attending them and removing them to fresh plants if the plants on which they have been herded wilt. In the fall the eggs of the plant lice are carried down into the nests of the ants below the frost line, and they are brought up again in the spring. The eggs or young are always placed on the same kind of plant from which they were taken. In exercising a protectorate over plant lice, the ants are not manifesting any particular altruism. In reality the plant lice emit drops of a sweet liquid called honey dew which the ants like. The ants stroke the aphids with their antennae to stimulate discharge of the secretion. For this reason the aphids are sometimes called "ant cows." In return for the honey dew the aphids receive the protection of the ants, and thus both species benefit. A similar relationship exists between ants and coccids, or mealy worms. The corn root lice are frequently destructive because they are assembled in great numbers on the roots of corn by ants.

There are many cases of symbiosis in nature. In Euglena the chlorophyll in the chloroplasts manufactures foodstuffs for the organism; and in return the plant material receives nourishment in the form of carbon dioxide and animal waste products. A similar relationship exists between hydra and algae. Such relationships between plants and animals are found in other protozoans, and

in coelenterates, ctenophores, turbellarians, annelids, rotifers, bryozoans, echinoderms, mollusks, and insects. One worm (*Convoluta roscoffensis*) ingests algae when in the larval stage and thereafter never feeds. This worm lives in the sand on the shores of the Pacific Ocean; and when the tide is out, the worm emerges from the sand and remains exposed to the light for some time. The light acting upon the chlorophyll stimulates photosynthesis, and the animal subsists on the products. In return, the algae derive nutriment from the body of the animal. The pollination of flowers by insects is a common example of symbiosis. The insects obtain nectar, and in return they transport pollen from one plant to another. Snail shells are frequently covered with algae which render the snails inconspicuous; and although the snail devours some of the algae at times, the plants are transported from place to place.

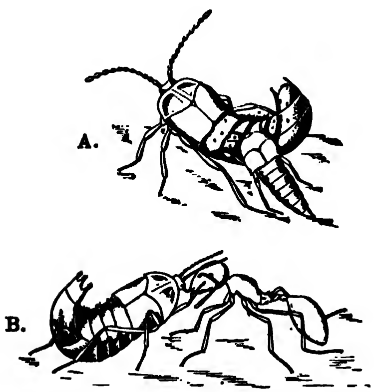


Fig. 10. Symbiosis. A. One insect being freed of mites by another insect; B. An ant feeding a beetle. After Wasmann from Wheeler.

The bodies of many animals contain bacteria and other fungi which live symbiotically with their hosts. There are numerous examples of symbiotic associations in which one organism lives within the body of another. Among the most astonishing of these are the beneficial relationships between microscopic flagellate protozoans found in the alimentary tract of termites, and their hosts. Cleveland has shown that these protozoans are necessary in order that the termites can digest the wood which they eat. However, we are concerned primarily with those examples which can be observed in the field.

The relationship between the *Pronuba* moth and the yucca plant is one of the most highly specialized symbiotic associations between plants and animals. The moth is the only animal that can effect the fertilization of the plant, and the plant is the only one that the moth can live in. The details of this relationship are given later. On the other hand, the pollination of red clover by the bumble bee is almost as striking and the bee is almost as necessary for the survival of the clover as the moth is to yucca.

In ant nests there are sometimes small claviger beetles which are protected by the ants. In fact they are even fed mouth to mouth, and ofttimes they are transported from place to place by the ants. In return the beetles produce a liquid that the ants relish. In other cases the guests in the ant nest act as scavengers and thereby keep the nest clean in return for the food which they obtain from the ants.

One hermit crab which is an inhabitant of the ocean places a sea anemone on its shell, and the stinging hairs discharged by the anemone serve to protect the crab and even obtain food for it. In return the anemone is carried about, and it is therefore constantly moved to new feeding grounds. In addition it receives left-overs from the crab's meals.

There are instances in which small fishes with adhesive discs on their heads attach themselves to sharks from whose bodies they take ectoparasites. The sharks are therefore relieved of annoying pests. The small fishes are carried about by the sharks, which do not molest them; and other fishes which would ordinarily devour them steer clear of the sharks. Thus there is a mutual benefit derived by the members of the association. The cowbird follows cattle; and as the feet of the cattle are planted the insects take to flight, thus revealing themselves to the bird. The bird also rests upon the back of cattle and feeds upon flies which alight there. Both the birds and cattle profit by this association. The crocodile bird of Africa renders a unique service to the crocodile in return for its diet. The crocodile burying its food in the mud gets leeches into its mouth. The leeches attach themselves to the inside of the jaws. The crocodile then goes to the shore, opens its mouth, and while the jaws are held open the bird enters and feeds upon the attached leeches.

Symbiosis is probably more extensive than we suspect, and the interspecific relations of animals should be carefully noted in order to determine their significance.

BIBLIOGRAPHY

Influence of Environment (Ecology)

Adams, C. C., *Guide to the Study of Animal Ecology.* Macmillan, 1913.

——, *An Ecological Study of Prairie and Forest Invertebrates.* Bull. Ill. State Lab. Nat. Hist., Vol. XI, Art. II, 1915.

Adolph, E. F., *Regulation of Size as Illustrated by Unicellular Organisms.* C. C. Thomas, 1930.

Allard, H. A., "Remarkable Musical Technique of the Larger Angular-Winged Katydid," *Science,* Vol. 67, 1928, p. 613.

Blake, I. H., *A Comparison of the Animal Communities of Coniferous and Deciduous Forests.* Ill. Biol. Mon., Vol. 10, No. 4, 1927.

Borradaille, *The Animal and Its Environment.* Henry Frowde, London, 1923.

Buxton, P. A., *Animal Life in Deserts: A Study of the Fauna in Relation to the Environment.* Edward Arnold and Co., 1923.

Chapman, R. N., *Animal Ecology.* McGraw-Hill, 1931.

Clements, F. E., *Research Methods in Ecology.* Univ. Pub. Co., Lincoln, Neb., 1905.

Crawford, S. C., *Nocturnal Adaptations.* Proc. Pa. Acad. Sci., Vol. 5, 1931.

——, "The Habits and Characteristics of Nocturnal Animals," *Quart Rev. Biol.,* Vol. 9, No. 2, 1934.

Dahlgren, U., *Production of Light by Animals.* Jour. Frank. Inst., 1917.

Davenport, C. B., *Experimental Morphology.* Macmillan, 1899.

Elton, Charles S., *Animal Ecology.* Sedgwick and Jackson, London, 1927.

——, *Animal Ecology and Evolution.* H. Milford, London, 1930.

——, *The Ecology of Animals.* Methuen Co., London, 1933.

Folsom, J. W., and Wardle, R. A., *Entomology with Special Reference to Its Ecological Aspects.* Blakiston, 1934.

Gadow, Hans, *The Wanderings of Animals.* Cambridge Univ. Press, 1913.

Guyer, M. F., *Animal Biology.* Harper, 1931.

Hart, C. A., and Gleason, H. A., *Biology of the Sand Areas of Illinois.* Bull. Ill. State Lab. Nat. Hist., Vol. 8, 1907.

Harvey, F. N., *The Nature of Animal Light.* Lippincott, 1920.

Henderson, L. J., *The Fitness of the Environment.* Macmillan, 1913.

Hingston, R. W. G., *Instinct and Intelligence.* Macmillan, 1929.

Holmes, S. J., *The Evolution of Animal Intelligence.* Henry Holt, 1911.

Howard, S. F., "Synchronous Flashing of Fireflies," *Science,* Vol. 70, 1929, p. 556.

Keeble, F., *Plant-Animals: A Study in Symbiosis.* Cambridge Univ. Press, 1912.

Lubbock, Sir John, *The Senses, Instincts, and Intelligence of Animals.* Appleton, 1888.

Lull, R. S., *Organic Evolution.* Macmillan, 1929.

Lydekker, R., *A Geographical History of Animals.* Cambridge Univ. Press, 1896.

MacDougall, W. B., *Plant Ecology.* Lea and Febiger, 1931.

Mast, S. O., *Light and the Behavior of Organisms.* John Wiley and Sons, 1911.

Mast, S. O., "Behavior of Fireflies with Special Reference to the Problem of Orientation," *Jour. Anim. Behav.*, Vol. 2, 1912, pp. 256–272.

McDermott, F. A., *Recent Advances in Our Knowledge of the Production of Light in Living Organisms.* Rept. Smithson. Inst. for 1911, pp. 345–362.

Newbingin, Marion, *Animal Geography.* Oxford Univ. Press, 1913.

Pearse, A. S., *Animal Ecology.* McGraw-Hill, 1926.

——, *Environment and Life.* C. C. Thomas, 1930.

Scott, W. B., *History of the Land Mammals of the Western Hemisphere.* Macmillan, 1913.

Shelford, V. E., *Animal Communities in Temperate America.* Univ. Chicago Press, 1913.

——, *Laboratory and Field Ecology.* Williams and Wilkins, 1929.

——, *Naturalist's Guide to the Americas.* Williams and Wilkins, 1926.

Shull, A. F., *Principles of Animal Biology.* McGraw-Hill, 1934.

Viosca, Percy, Jr., *An Ecological Study of the Cold-Blooded Vertebrates of Southeastern Louisiana.* Copeia, No. 115, 1923.

——, "Distributional Problems of the Cold-Blooded Vertebrates of the Gulf Coastal Plain," *Ecology*, Vol. VII, No. 3, 1926.

——, "Spontaneous Combustion in the Marshes of Southern Louisiana," *Ecology*, Vol. XII, No. 2, 1931.

Wallace, A. R., *The Geographical Distribution of Animals*, 2 vols., Macmillan, 1876.

Weaver, J. E., and Clements, F. E., *Plant Ecology.* McGraw-Hill, 1929.

Welch, P. S., *Limnology.* McGraw-Hill, 1935.

Williams, S. H., *A Systematic Guide to Field Zoölogy.* Author's mimeographed edition. Univ. of Pittsburgh, 1927.

——, *A Preliminary Report on the Animal Ecology of Presque Isle.* Proc. Pa. Acad. Sci., Vol. 5, 1931.

Parasites

Boyce, R. W., *Mosquitoes or Man? The Conquest of the Tropical World.* J. Murray, London, 1910.

Braun, Max, *Animal Parasites of Man.* J. Bale, Sons, and Danielsson, 1906.

Braun, M., and Lühe, M., *Handbook of Practical Parasitology* (translated from German by L. Forster). J. Bale, Sons, and Danielsson, 1910.

Chandler, A. C., *Introduction to Human Parasitology.* John Wiley and Sons, 1930.

Clark, A. H., *Animals of Land and Sea.* Van Nostrand, 1927.

Comstock, J. H., *Introduction to Entomology.* Comstock Pub. Co., 1933.

Doane, R. W., *Insects and Disease.* Henry Holt, 1910.

Ewing, H. E., *Manual of External Parasites.* C. C. Thomas, 1929.

Ferris, G. P., "Some Ectoparasites of Bats," *Ent. News*, Vol. 27, 1916, pp. 433–438.

Hegner, R. W., *College Zoölogy*. Macmillan, 1932.

——, *The Parade of the Animal Kingdom*. Macmillan, 1935.

Johannsen, O. A., and Riley, W. A., *Handbook of Medical Entomology*. Comstock Pub. Co., 1915.

Linton, E., and Stiles, C. W., *Information concerning Parasitic Worms in Fish*. U. S. Bur. Fisheries, Econ. Circular No. 21, 1916.

Macdougal, D. T., and Cannon, W. A., *The Condition of Parasitism in Plants*. Carnegie Inst. Wash. Pub. 129, 1910.

Massart, J., and Vandervelde, E., *Parasitism: Organic and Social*. Scribner, 1907.

Matheson, Robert, *Medical Entomology*. C. C. Thomas, 1932.

Metcalf, C. L., and Flint, W. P., *Destructive and Useful Insects*. McGraw-Hill, 1928.

Moore, J. Percy, and others, *The Leeches of Minnesota*. Geol. and Nat. Hist. Survey of Minn. (Zoöl. Ser. No. 5), 1912.

Nuttall, G. H. F., Warburton, C., Cooper, W. F., and Robinson, L. E., *Ticks; a Monograph of the Ixodoidea*. Harvard Univ. Press, 1908 to 1915.

Patton, W. S., and Cragg, F. W., *A Textbook of Medical Entomology*. Christian Literature Society for India, 1913.

Pearse, A. S., *Animal Ecology*. McGraw-Hill, 1877.

Pearson, Leonard, *Diseases of Poultry*. Pa. Dept. of Agric. Bull. 17, 1896.

Pierce, W. D., *Sanitary Entomology*. Richard Badger, Boston, 1921.

Riley, C. V., *Parasitism in Insects*. Proc. Ent. Soc. Wash., Vol. II, 1893.

Riley, W. A., and Christensen, R. B., *Guide to the Study of Animal Parasites*. McGraw-Hill, 1930.

Russel, H., *The Flea*. Cambridge Univ. Press, 1913.

Shipley, A. E., *Nemathelminthes*, Vol. II. Cambridge Nat. Hist., London, 1922. This series is a valuable reference for all animal groups.

Shull, A. F., *Principles of Animal Biology*. McGraw-Hill, 1929.

Stiles, C. W., *Parasitism*. Proc. Ent. Soc. Wash., Vol. III, 1893.

Stunkard, H. W., "Parasitism: A Biological Phenomenon," *Sci. Monthly*, 1929, pp. 349–362.

Underhill, B. M., *Parasites and Parasitosis of Domestic Animals*. Macmillan, 1920.

Wheeler, W. M., "Insect Parasitism and Its Peculiarities," *Pop. Sci Monthly*, Vol. LXXIX, 1911.

CHAPTER III

THE COLORS OF ANIMALS

The coloration of animals has long been a matter of controversy between two groups of biologists, the naturalists and the physiologists. The former have, until recently, contended that the coloration of animals is purely purposive. That is, they believe that the colors and color patterns of animals are produced by some directive force or forces for purposes of security.

The physiologists, or at least most of them, have insisted that all coloration is purely physiological and that its production, deposition, distribution, and selection have little to do with rendering any special service to animals and little or no connection with extraneous factors. More recently, however, biologists recognize certain valid claims of both groups.

There is no question that green caterpillars are safer on green foliage, or that spotted fawns are less conspicuous in dense forests than are their parents. It is also obvious that the white coats of arctic animals have a protective value in snow-covered regions.

While most colors are the products of physiological activity, there are other factors which help to determine the set patterns which characterize most animals. It has been shown that heredity, genetic mutations, humidity, food, temperature, light, and disease all play an important part in the production and alteration of color and that natural selection finally plays some part in determining the colors and color patterns which eventually continue in most animal groups.

However, in considering color, it must be remembered that we are dealing with a variable quality, to which we as individuals respond in different ways. We must also bear in mind that colors are psychological products. When we attempt to interpret colors in other animals, we must not lose sight of the fact that nearly all of the lower groups have sensory apparatus entirely different from our own. Because of the great variety of vastly different structures through which animals perceive, these organisms may not only respond to light frequencies that are different from those

which stimulate the human eye, but their sensory perception of these cannot be judged in terms of the human interpretation.

There are three distinct types of coloration in the animal world. They are: (1) pigmental, (2) structural, and (3) combination

FIG. 11. Does the skunk have warning coloration? From an exhibit in the Carnegie Museum, Pittsburgh.

colors. The first of these implies that distinct chemical pigments are present in the exposed structures of some animals, and that these produce their characteristic tints. The distribution of pigment in exposed structures such as hair and skin is peculiar to individual species. In some animals such as salamanders, the pigment is present in chromatophores or melanophores which are sometimes capable of movement in response to light effects. Frequently a pigmental color is modified or subdued by the presence of another contrasting or interference color which is usually structural.

Structural colors are those produced by the modification of exposed surface structures. These modifications consist of minute striations, punctuations, and sculptured areas. These physical alterations diffuse the light that strikes them, and they reflect the rays of different lengths and frequencies which we interpret as colors.

The reader will, of course, keep in mind that white light is a combination of all colors and that the visible colors of objects are those which are reflected from them. White light is broken up into its constituent colors (spectrum) by diffusion, diffraction, reflection, and refraction. The invisible colors, or those that are not revealed when an object reflects a characteristic color as the light strikes it, are those which are absorbed by the object. A thin, transparent film which covers the wings of tiger beetles, for instance, is responsible for the bright green colors of some of them. The film causes a structural analysis of the light in this case since no green pigment is present. The minute striations on the wing scales and the wing covers of many insects are entirely responsible for their colors. Most colors of birds are structural. The silvery white and milky areas on some spiders are due to optical effects produced by light reflected from air-filled scales, while the silver spots on the silver spot butterfly (*Argynnis*) are merely scaleless, mirror-like areas which reflect the light. Structural colors do not fade, but they may be altered by dust and temporarily obliterated by water.

Fig. 12. The arctic hare or snowshoe rabbit in winter coloration. From Williams, *The Mammals of Pennsylvania.*

Combination colors are exactly what their name implies—a combination of pigment and structural modification. It is very likely that most animal colors are of this sort. The effects of pigmental and interference colors may be classified as combination colors. The color of the brilliant blue *Morpho* butterflies of South

America and that of our native mourning cloak, as well as those of many birds, insects, and mammals, are combination colors. In the butterflies of the family *Lycaenidae* the colors are invariably of this sort.

In general, color is a tremendous subject, with chemical, physical, physiological, and behavioristic phases. Green caterpillars usually get their color from the foliage eaten. The larva of the cabbage butterfly (*Pieris rapae*) is green; but in the adult the color is due to the presence of water-soluble uric acid in the scales on the wings. In the pupal stage, the rate of metabolism is high; and considerable waste is produced. Urea is a characteristic waste

FIG. 13. The white coat of the weasel in winter is a protection when the ground is covered with snow.

product of animal metabolism; and since there is no anal opening for the discharge of fecal substances in the pupa, some of the urea is secondarily utilized. The wing scales are hollow, flattened sacs; and the chemical substances are deposited in them. These substances or pigments give to the scales their colors. The yellow pigment in the tiger swallowtail (*Papilio turnus*) is said to be an almost pure pigment. Most pigments are usually mixtures.

It has been suggested that variations in color may be due to physical factors such as light, humidity, temperature, and disease. Strong sunlight has a tendency to bleach many pigments. Luna moths (*Actias luna*) kept in exposed, glass-covered cases usually become pale in a few months. On the other hand, black beetles usually emerge from the pupal cases with a light tan color which is darkened by the action of atmospheric oxygen on the freshly formed chitin. Birds of a single species are darker in regions where the atmosphere is humid. Some moths which have a wide range

are darker in the North and lighter in the South, probably because of temperature differences. There are nine times as many *Papilio* butterflies in South America as there are in North America, and yet there are only twice as many colors in the South American fauna. Much could be written on the relations between color and climate, but the naturalist is primarily interested in color from the standpoint of a human observer who sees an organism in its natural haunts. From his point of view he attempts to interpret the part that colors and color patterns play in contributing to the survival of the organism. He also looks for any effects color may have on the attitude the organism assumes toward its background and toward other organisms of its own and of other kinds.

FIG. 14. The tiger swallowtail, *Papilio turnus* (*Papilionidae*).

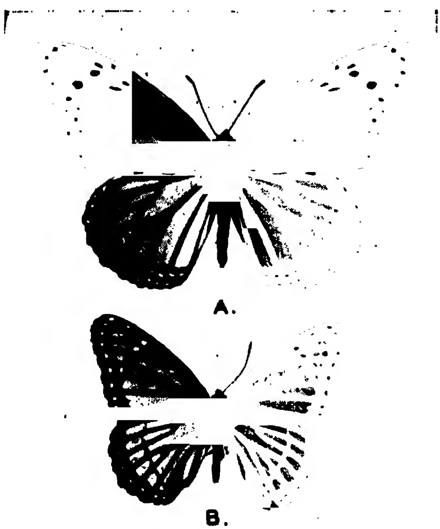


FIG. 15. Mimicry. A. The monarch, *Danais plexippus* (*Nymphalidae*); B. The viceroy, *Basilarchia archippus* (*Nymphalidae*).

In the field, it can be readily noted that animals on the open plains are usually more or less uniformly colored (horses, cattle, antelope, bison) unless their body forms are otherwise adapted to concealment. Arctic animals living on snow and ice are predominantly white (ptarmigan, arctic fox, arctic hare, polar bear, snowy owl). In temperate zones where snow is present for a few months, some forms like the weasels (Fig. 13) are white during the winter months only. The animals in open sections where there are tall grasses and a sparse scattering of trees and shrubs are striped or marked with huge spots (tigers, zebras, giraffes). The

inhabitants of forests are spotted (leopards, jaguars, jungle deer, and the young of tapirs, peccaries, and Virginia deer). In the low grasses the pattern is definitely striped (meadow lark, sparrows). In all of the above cases, the specimens, while they may appear conspicuous in museum cases, are difficult to see in their native haunts. When the color pattern is not adaptive, the animals have other efficacious means of protecting themselves such as swift flight (deer, adult peccaries), powerful teeth, offensive odors, horns, or other devices.

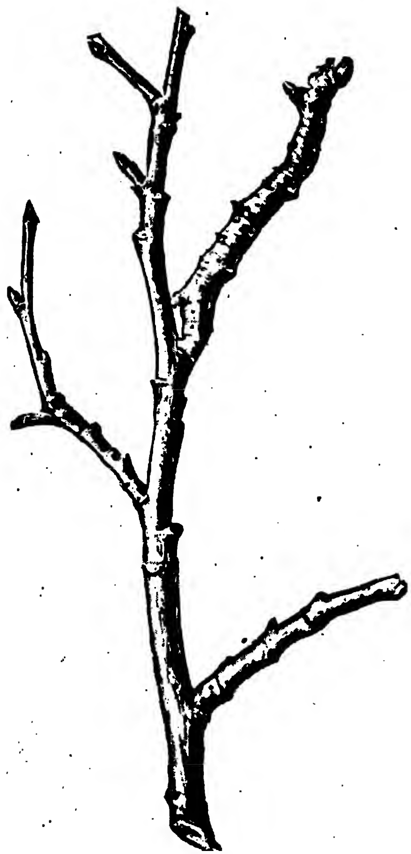


FIG. 16. Protective resemblance. Measuring worm on twig. After Kellogg.

Countershading is characteristic of most animals. The light underside and darker back neutralize shadows and otherwise render protection. The line dividing the upper and under colors breaks the outline or silhouette of the animal and demonstrates the principle of camouflage. Stripes, spots, and bands are all illustrations of camouflage, a principle of concealment used extensively in war, on ships, tanks, trucks, and along lines of march.

The lines across the face of the raccoon; the spots on a leopard or jaguar; the stripes on a tiger or female red-winged blackbird; the mottled pattern and lines on quail; the white band across the back of a red-headed woodpecker in flight; and a host of other examples illustrate how these markings disrupt the uniformity of color pattern and destroy the outline of the body in the same way

that stripes and bands on war-time ships made them less visible at a distance. The writer was amazed at the rapidity with which a jaguar disappeared in the jungles. It seemed to suddenly melt away as it turned to escape.

Conspicuous areas such as the white cotton-tail of the rabbit; the white rump of a flicker; the white under-tail of the Virginia deer; the white outer tail feathers of chewinks, juncos, meadow larks, and vesper sparrows are visible when those animals are disturbed or in flight; and they may be called flash colors, recognition colors, or signal colors.

Among some animals, notably birds and insects, there is frequently a distinct difference between the colors of males and females. The male is usually the more brightly colored. Tiger beetles, moths, red-winged blackbirds, goldfinches, scarlet tanagers, ring-necked pheasants, and numerous others illustrate this. In some cases, such as the tanager and goldfinch, the gaudy coat of the male is temporary and confined to the mating season, after which the bright colors are lost. While many of the color changes are probably due to physiological processes, such as sex hormones, the gaudy coat of the male is, nevertheless, attractive to the female; and it undoubtedly expedites and probably insures mating activities. If this is so, and the evidence indicates that it is, then the functional values of the courtship colors cannot be denied; for after all, the female has hormones, too. In fact, there is some evidence that would indicate that brilliant color spots, stripes, and bands on some creatures are end results of a long period of selectivity on the part of the females which frequently manifest a susceptibility to flashy colors.

That there is some relationship between color and habits is illustrated by the vireo which rests concealed within the recesses of the foliage, waiting for insects to pass. A brilliant coat would be disadvantageous because of its conspicuousness. The dull coloration adds to its concealment and to its chances of capturing flying insects, which are also attracted to and repelled by color. The mole, which leads a subterranean existence, unexposed to light, is uniformly dark; and it lacks the countershading that is characteristic of terrestrial, aquatic, and arboreal animals. The twig-like body form of the walking-stick and of several caterpillars; the leaf-like form of the mantis; the dead-leaf-like form of the Indian butterfly *Kallima;* the thorn-like appearance of some mem-

bracids; and the gall-like appearance of some beetles and spiders, all of which may cause them to be overlooked by enemies, cannot be explained in purely physiological terms. But the great variety of color patterns, many of which cannot be interpreted in terms of environment or in terms of survival value, indicate that the interpretative analysis of color becomes somewhat complicated and demands classification.

Classification of Colors

Because of the extreme difficulty in describing colors due to the variability of the individual conception of them, biologists have established an international code of colors for world-wide application. Since we are primarily interested in the adaptive side of color, an abbreviated, ecological classification will suffice.

1. **Concealing coloration** (cryptic colors). These include those colors and color patterns which resemble the background or at least part of it. They render their possessors inconspicuous and therefore enable them to escape observation by their enemies. Green caterpillars on green plants; ruffed grouse and quail among dead leaves; the whip-poor-will on a dead log; countershading of most animals; the olive green of many birds; green katydids among green plants; the mottled gray of bark moths; the leaf-like wings of the praying mantis; the white coats of weasels in winter; the rough, warty, dirt-colored skin of the toad; the green back of the green frog, resting on the surface of an algae-filled pond; the mud-colored bottom nymphs of dragon flies; the stone-colored larvae of brook beetles and stonefly nymphs; and thousands of other examples illustrate how the color patterns of animals make them difficult to see. The bars, stripes, bands, and spots, already referred to, are concealing colors. Most protectively colored animals remain motionless in the presence of danger. Even the changing colors of chameleons, tree frogs, and numerous fishes are devices which enable them to quickly transform their outer aspects in order to blend into the color of their backgrounds.

2. **Aggressive coloration** (anticryptic colors). This type of coloration, which also resembles the background, is possessed by animals which are predatory in their habits but which usually lack the ability to overtake their victims by pursuit. They usually lie in wait for their victims to approach within reach of their seizing apparatus. Because of their resemblance to the setting in

which they live, they are not readily discovered by their victims until it is too late. Leaf mantises, which are poor fliers and slow crawlers, are excellent examples of aggressive coloration. Certain decorator crabs will pluck sponges, kelp, or sea anemones and hold them in their claws before them. They are thus able to advance on their victims behind a protecting screen of harmless organisms.

3. **Mimicry and protective resemblance** (pseudaposematic colors). In this group should be included those animals which

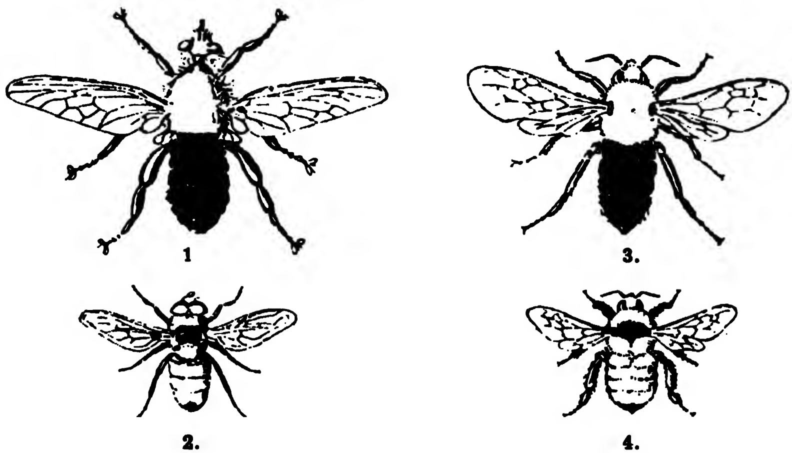


FIG. 17. Flies that mimic bees. 1., 2. Syrphus flies; 3. Queen bumble bee; 4. Female worker bumble bee. After Plath, *Bumblebees and Their Ways*, The Macmillan Company.

have a coloration similar to some other animal generally avoided by predators, or to parts of plants. The caterpillar of the brimstone moth (*Geometridae*) resembles a twig broken off at the end; and when disturbed, it will extend one end of its body at an angle similar to that of the twigs on the plant (Fig. 16). There it will remain motionless until the danger has passed. It so closely resembles a twig that it usually escapes observation. The body form of the walking-stick alsc mimics the stem of plants. Spiders mimic bugs, ants, and portions of plants. Flies mimic bees (Fig. 17) and other stinging hymenopterous insects. The viceroy butterfly mimics the inedible monarch so closely that it is seldom taken by birds which avoid the monarch. Leaf-hoppers mimic thorns and bracts, while spiders and beetles sometimes mimic plant galls.

Quite frequently the mimic acts in the same way as its model, although this is not always the rule. Sometimes the resemblance between mimic and model is so nearly exact that the one will court the other. Mimicry is both for protection and aggression (pseudepisematic colors).

4. **Warning colors** (aposematic colors). While it is debatable as to the justification for classifying any color patterns as primarily intended to warn other animals to "keep their distance," the fact

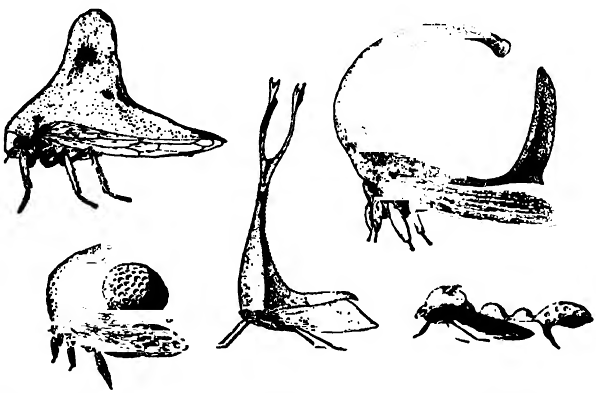


FIG. 18. Some unusual shapes assumed by tree-hoppers (*Membracidae*). After Funkhouser, courtesy Cornell Agric. Exp. Sta.

that many dangerous and disagreeable animals have a pronounced conspicuousness would suggest that such claims have a basis of fact. The prominent white stripe on the skunk and the brilliant colors of many stinging wasps and biting ants, as well as the gaudy colors of the poisonous coral snakes, all of which are unpleasant to encounter, certainly are obvious labels by which they can be easily identified. The coloration of the owl's-head moth and the large eye spots on the thorax of the eyed elater (*Alaus oculatus*) beetle are considered by some to function as a warning to other animals. The writer is rather inclined to believe that purposive warning colors do not exist as such.

5. **Recognition and signal markings** (episematic colors). There is little doubt that certain color markings might well serve for purposes of identification. The white rump on the flicker which is so conspicuous in flight; the white outer tail feathers of many birds (vesper sparrow, junco, chewink); the white tails of deer and rabbits; and numerous other color characters are displayed

in flight; and when disturbed, as has already been suggested, these are flash colors which may warn others against danger or they may serve as characters for their quick identification by others of their kind. Certainly the bright hair tufts on the legs of the males of some dolichopodid flies are identification marks. When the passing female sees the tuft on the uplifted leg of the male, she descends. Likewise, the bright pedipalpi of male spiders, which are so conspicuously displayed in courtship, are also indubitable marks of identification. Some flightless Orthoptera raise their wings to display color markings to other individuals in much the same manner as do birds. There is no doubt that the white outer tail marking of vesper sparrows and juncos and the white rumps of the bobolinks, which travel in flocks, serve as signals which make it easier for the flocks to keep together.

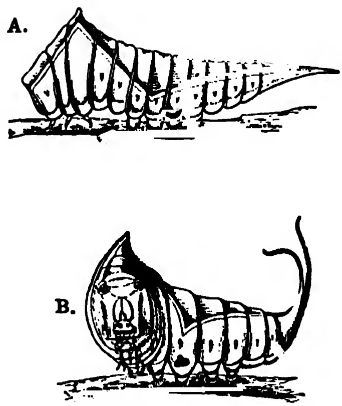


FIG. 19. Larva of the puss-moth, *Cerura sp.* A. Larva in normal attitude; B. Larva disturbed. From Kellogg, *American Insects*, courtesy Henry Holt and Co.

6. **Courtship colors** (epigamic colors). While the principles of some of the other types of coloration might be open to question, there is no doubt as to the validity of courtship colors. They are even manifest among humans—artificial ones, of course.

The brilliant male birds disport themselves rather flamboyantly before the less gaudy females during the mating season. Since many birds, salamanders, insects, mammals, and fishes exhibit bright colors only during the mating season, there is every reason to accept these colors as being of courtship value. In dioecious animals (and in most dioecious plants) bright colors serve as devices for insuring fertilization.

One indication of color value is that those organisms which do not possess some sort of protective coloration usually have other efficacious means of defending themselves. This type of coloration is usually lacking in animals which can dart quickly into underground burrows, but it is present as a rule in those animals which scamper into trees. Nocturnal animals lacking powerful defense are frequently dark colored and therefore inconspicuous at night.

While the writer is reticent to grant too much to the claims of the old school of naturalists, he cannot completely subscribe to the claim that color is unaffected by external or environmental conditions. As a final illustration, let us consider the case of the ostrich. The male bird is very conspicuous while the female is rather dull. The hen sits on the eggs during the day; and her somber, brownish-gray color makes her rather inconspicuous, especially since she rests her neck and tail on the ground while sitting. The male bird sits on the eggs at night when his black hue matches the darkness and therefore renders him invisible to possible enemies.

The student can make many observations on the colors of animals in all groups, and such observations will result in a classification of colors according to the service they render to the animals. Behavior is definitely connected with color in many species.

Luminescence; Light-Producing Organisms

While the sun, the moon, and the stars are ordinarily considered as the sources of light in nature, it often happens that plants and animals themselves radiate light. In fact luminescence, or light production, is quite an extensive phenomenon in nature. Myriads of organisms, plant and animal, emanate visible light, while many chemical substances not only produce light which can be perceived by the human eye, but they also produce waves of such length as to be imperceptible. The invisible rays of light from radioactive minerals have played an important part in earth changes. However, the naturalist is interested in those phases of light production which enter into the realm of the organic world, affecting the lives and behavior of plants and animals and illustrating further the diversity of biological processes.

There are many luminescent animals in the ocean. These include representatives of many phyla such as protozoans, jellyfishes, corals, ctenophores, sea pens, worms, brittle stars, prawns, squids, starfishes, angler fishes, and ascidians. A deep-sea shark is luminous on the underside due to the presence of many small light-producing organisms which attach themselves to the skin. Other bathymeric fishes have light-producing organs on their entire bodies; and some of them have these organs arranged in lateral lines along the body.

While the ocean is rich in these luminescent forms, none of them is to be found in fresh water. On land there are many luminescent

organisms, especially in the tropical regions. Among the light-producing animals there are glow worms, click beetles, earthworms; and fireflies with their luminous eggs and larvae. In the northern states the firefly is the only common one to be seen. On warm humid summer nights thousands of these can usually be seen flickering their lamps over fields and meadows.

Luminescence is often referred to as phosphorescence; but since no phosphorus is involved, the term is erroneously applied. All luminescence in animals is associated with oxidation. Most luminescent animals are illuminated only at intervals, and the glow is not steady. The flashes occur particularly when the organisms are disturbed; and at these times the glow may be extended longer than usual. In most species, however, the flashes occur at regular intervals. In some of these animals luminescence occurs only during the breeding seasons.

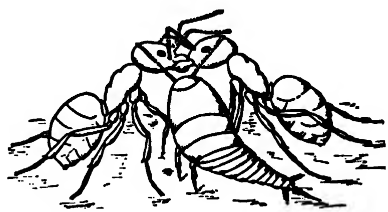


FIG. 20. A thysanuran stealing food from a pair of ants. After Janet.

The light emitted exhibits only a small part of the spectrum which is nearly like that of many luminescent chemical substances, and it appears only at certain temperatures which are characteristic for each species. The light produced by animals has no X-ray effects. Recent researches show that the light from fireflies does not penetrate wood, paper, leather, and flesh in sufficient quantities to affect photographic film as some earlier textbooks aver, although the insects may emit enough light to take their own photographs on the surfaces of objects.

In America the majority of light-producing terrestrial animals are confined to the tropical regions, and their numbers decrease progressively northward. In some southern states, and particularly in Central and South America, the most common and spectacular luminescent animal is a large click beetle, *Pyrophorus* (family *Elateridae*). It has two large organs on the lateral margins of the thorax. These resemble eyes and from them emanates a brilliant, amber-colored light which illuminates the surrounding foliage on dark nights. The glow is extended for a much longer period than in our native firefly. In some sections of Central and South America these beetles are used by women as hair ornaments at night, and

the natives sometimes place numbers of them in bottles which they use as lanterns.

Some of these beetles have a luminous patch on the underside as well; and as one of them ascends a sloping caladium leaf (elephant ear) in the darkness of a jungle night, it looks like an automobile coming over the crest of a distant hill, its tail light casting a trailing glow behind. In our native fireflies or lightning bugs (Coleoptera—*Lampyridae*) the light emanates from the underside of the abdomen; and it comes in short, more or less irregular flashes.

The females of some of our native fireflies are wingless; and they mature as larvae in form. These also produce light; and they are frequently called glow worms, being confused with the glow worm of England. It has been suggested that the larva within the egg is also luminous; and in the darkness the luminosity of the unhatched young is sufficient to reveal the body form within the egg.

Occasionally when a stone is lifted or turned over in the woods at night, a tiny, rapid flicker of light can be observed. This is produced by collembolans (see Insects), some of which produce momentary flashes of light. Gnats and midges are sometimes luminous, but their luminosity is due to a bacterial disease which attacks them, just as dead fish on the beach sometimes glow at night because of luminous bacteria which develop in them.

In the ocean water the iridescence of the wave caps in the darkness is due chiefly to a protozoan called *Noctiluca*. Another protozoan, *Pyrocystis*, which is much less common, is sometimes present in the surface water in great numbers; and it is much more brilliant than *Noctiluca* as a rule.

Sometimes the feet and bills of birds are luminous; and in Europe luminous birds, their whole bodies exhibiting illuminated outlines, are sometimes seen flying through the air on dark nights. Apparently this phenomenon has been observed since ancient times, and it has been the basis for some queer superstitions. It is explained, however, by researches which were made on Norfolk owls in England. Many plants are luminous, especially fungi; and when the birds rub against them, the luminous material adheres to the feathers. It must be an eerie sight to see a luminous bird rapidly traveling through the darkness; and it is no wonder that the credulous populace has connected them with weird beliefs. Sometimes the feet of waterfowl become covered with the small, microscopic, luminous organisms which inhabit sea water; and the

bills of birds such as the whip-poor-will and the nighthawk are often luminous because they devour fireflies. The teeth of bats have often appeared distinctly illuminated at night because of their diet of fireflies. In some southern states there are luminous centipedes and earthworms.

There are also other strange and mysterious lights in nature which have commanded the interest of people since earliest times. Their sources have been the subject of speculation for generations, and the explanations which have been advanced to account for their origins are illustrative of "wild flights of imagination and fancy." The familiar "foxfire" of damp woods has been the basis of many ghost stories. It is due to chemical action in decaying wood. A great many fungus plants emanate a visible light, and scientists have shown that the green leaves of many plants and the wings of butterflies also throw off light rays which affect sensitive photographic film.[1] These rays are not perceptible to the human eye, however.

The "will-o'-the-wisp" of folklore fame is a real phenomenon. On hot summer nights the water over a swamp may be illuminated by feeble flickerings of light. As a rule the flashes are of short duration; but sometimes the light moves for a considerable distance, like a traveling ball of fire. This is the "will-o'-the-wisp" of poetic fame. It is caused by the spontaneous ignition of gases which bubble up from the swamps. Methane or marsh gas (CH_4) is a product of decaying vegetation under water. The gas is highly inflammable and its combustion causes the familiar lights so often observed in swamps.

St. Elmo's light is a phenomenon frequently observed at sea, especially in tropical and arctic regions. The light is a steady glow that ofttimes illuminates the entire ship. The margins of the hull as well as the mast and rigging become covered with a greenish fire as brilliant as the hands and dial on some clocks and watches. It is as though these parts were painted with radium; and sometimes the phenomenon lasts for several minutes. The writer had the good fortune to observe this phenomenon on a schooner in the Caribbean Sea some years ago. The light is due to static electricity in the atmosphere, and it is attracted to the ship just as lightning is.

However, luminescence in animals is of entirely different origin, although its production is not completely understood. As has been

[1] See Clark, *Butterflies of the District of Columbia*, Bull. 157, U. S. Nat. Mus.

stated, it is always associated with oxidation. Researches have shown that luminescence is due to the action of an enzyme called luciferase on a protein substance known as luciferin, in the presence of oxygen. This explanation has been greatly amplified by more recent investigations of an extremely technical character.

In the discussion of light, the purpose and function of luminescence is alluded to. In deep-sea forms it serves to attract possible victims just as a light attracts insects of various kinds. It also assists animals which travel in great schools to keep together. In such animals as worms, noctiluca, pyrocystis, dinoflagellates, ctenophores, jellyfishes, and numerous others it may possibly repel enemies and therefore serve as a defense mechanism. In fireflies, marine worms, and click beetles it undoubtedly functions in sex attraction.

Albino Animals and Albinism

While the usual, more or less fixed, color patterns of animals may be frequently modified by environmental factors such as food, light, moisture, temperature, and disease, it also happens in practically all animal groups in which color is normally present that individuals are produced which have no apparent coloration at all, and they are therefore white. This is due to a total or almost total absence of pigment, and these individuals are known as albinos (L. *albus*—"white").

Among mammals this is not such a rare phenomenon as is commonly supposed; and white deer, groundhogs, elephants, rhinoceri, bats, rats, mice, monkeys, and other white individuals in many species have often been recorded. Even human albinos are not uncommon. Such persons have snow-white hair, very whitish skin, and pink eyes. It has been shown that in pure albinos even the tissues lack their normal pigments. The pink eyes are not due to the presence of pigment but rather to a total lack of it. Therefore the numerous blood capillaries present in the eye, which are normally obscured by pigment in the iris, are exposed, thus giving the eye its pink or reddish color. The skin is normally pink because of these capillaries. There are many cases on record of albino Ethiopians in whom the black pigment is absent.

But albinism is not confined to mammals alone. It frequently occurs in birds, and white robins, white crows, and white blackbirds are occasionally seen. In fact, albino individuals of many

species of birds, snakes, frogs, and other animals are sometimes seen.

It has already been suggested that albinism is due to a lack of pigment, and the remarkable feature of this condition is that it must be classed as a genetic mutation because it is a transmissable and inheritable character. This means that the offspring of two mated pure albinos will all be white. Since this is true, it might well be asked, "Why is it that more albinos are not found in nature?" However, there are several factors involved in the determination of their numbers.

Geneticists recognize that some characters are dominant while others are recessive. In other words, when two opposite or allelomorphic characters are combined, one of them is temporarily submerged. Color is dominant over albinism; and if an albino mates with an individual of color, the albino character is temporarily lost; and all of the offspring will have color just as in the Mendelian crossing of a red-flowered pea with a white-flowered one, in which all of the first generation (F_1) will be red. Even in the second generation (F_2), only one-fourth of the offspring will be white. These ratios, of course, apply only to large numbers.

In nature there are fewer opportunities for albinos to mate, and therefore only a few are produced. Furthermore, a white coat is protective only to a few animals such as snowy owls, arctic hares and foxes, and to weasels in their winter fur, which is white. In other animals, such as deer and blackbirds, a white coat renders them conspicuous; and they are subject to greater dangers. The survival value of albinism is thus opposed to its frequent occurrence.

It must not be supposed that all white individuals are albinos. Cave-inhabiting animals are usually whitish because they have not been exposed to the stimulus of light. The white of weasels in winter, which is physiological, develops as a protective response to a background of snow. In these forms which exhibit a seasonal change in color, some color always remains; and the eyes retain their normal pigments. It has already been indicated that albinism implies a complete lack of pigment.

Then, too, there are species such as egrets, white leghorn chickens, poland china pigs, horses, spitz dogs, and guinea pigs which are normally white. However, in these animals, color factors are present.

Physiologists have shown that some relation exists between the presence of the color factor in the genetic constitution of an animal and the production of tyrosinase, an enzyme that changes chromogenic substances, present in the *blood* of animals, into melanin-like pigments. There is an absence of this enzyme in albinos.

BIBLIOGRAPHY

Color

Beddard, F. E., *Animal Coloration.* Macmillan, 1892.

Harrison, J. W. H., and Garrett, F. C., *The Induction of Melanism in the Lepidoptera and Its Subsequent Inheritance.* Proc. Roy. Soc., London, B 99, 1926.

Hopkins, F. G., "The Pigments of the Pieridae," *The Entomologist*, Vol. 28, 1895.

Judd, S. D., "The Efficiency of Some Protective Adaptations in Securing Insects from Birds," *Amer. Nat.*, Vol. 33, 1899, pp. 461–484.

Longley, W. H., "Studies on the Biological Significance of Animal Coloration," *Amer. Nat.*, Vol. 51, 1917.

Mason, H. W., "Structural Colours in Insects," *Jour. Phys. Chem.*, Vols. 30, 31, 1926 to 1927.

Mayer, A. G., "The Development of the Wing Scales and Their Pigment in Butterflies and Moths," *Bull. Mus. Comp. Zoöl.*, Vol. 29, 1896, pp. 209–236.

——, "On the Color and Color Patterns of Moths and Butterflies," *Proc. Bos. Soc. Nat. Hist.*, Vol. 27, 1897, pp. 243–330.

McAtee, W. L., *The Experimental Method of Testing the Efficiency of Warning and Cryptic Coloration in Protecting Animals from Their Enemies.* Proc. Acad. Nat. Sci. Phila., Vol. 64, 1912.

Michelson, A. A., "On Metallic Colouring in Birds and Insects," *Phil. Mag.*, Ser. 6, 21, 1911, pp. 554–567.

Packard, A. S., "Change of Color and Protective Coloration in a Flower Spider, Misumena vatia," *Jour. N. Y. Ent. Soc.*, Vol. XIII, 1905, pp. 85–96.

Palmer, L. S., *Carotinoids and Related Pigments.* Chemical Catalog Co., New York, 1922.

Pearse, A. S., *Animal Ecology.* McGraw-Hill, 1926.

Poulton, E. B., *The Colours of Animals.* Appleton, 1890.

Punnett, R. C., *Mimicry in Butterflies.* Cambridge Univ. Press, 1915.

Robson, Guy C., *The Species Problem.* Oliver and Boyd, London, 1928.

Rogers, C. G., *Textbook of Comparative Physiology.* McGraw-Hill, 1927.

Schroder, C., *Handbuch der Entomologie.* G. Fischer, Jena, 1929.

Shelford, V. E., *Color and Color Pattern Mechanism of Tiger Beetles,* Ill. Biol. Mon. 3, 1917.

Sinnott, E. W., and Dunn, C. L., *Principles of Genetics.* McGraw-Hill, 1932.

Swynnerton, C. F. M., *Experiments and Observations on the Explanation of Form and Coloring.* Jour. Linn. Soc., London, 1916.

Thayer, G. H., *Concealing Coloration in the Animal Kingdom.* Macmillan, 1909.

Tower, W. L., *The Development of the Colors and Color Patterns of Coleoptera.* Univ. Chicago Decen. Pub. 10, 1903.

Webster, F. M., *Warning Colors, Protective Mimicry, and Protective Coloration.* 27th Ann. Rept. Ent. Soc., Ontario, 1897, pp. 80–86.

Weisman, A., "New Experiments on the Seasonal Dimorphism of Lepidoptera" (translated by W. E. Nicholson), *The Entomologist,* Vol. 29, 1896, pp. 29–39.

Wigglesworth, V. B., *Uric Acid in the Pieridae.* Proc. Roy. Soc., London, B 97, 1924.

Williams, S. H., *The Mammals of Pennsylvania.* Univ. of Pittsburgh Press, 1928.

CHAPTER IV

THE DEFENSES AND LIFE SPAN OF ANIMALS

The means by which animals protect themselves against innumerable enemies and forces are almost as diverse as the animals themselves. In many cases the defensive structures serve other purposes as well, particularly as offensive weapons. In a great number of animals, the formidable weapons of defense are secondary sexual characters; and they are therefore possessed by only one sex, usually the male. In such cases, it often happens that the one equipped with the formidable device assumes the responsibility for the safety of the other. In some animals, such as stag beetles and deer, the chief weapons of defense are embellishments for mating purposes; and not infrequently the males will engage in bitter and deadly combat during the mating period. In bees and wasps, the females have the weapons in the forms of stings, which are modified ovipositors.

Aside from structural defenses, animals also have their physiological processes so modified as to contribute to their survival. Even the ability to regenerate lost parts and the ability to heal wounds are defense mechanisms; and the faculty of practicing autotomy enables many species of animals to escape what would otherwise be certain death. Color and color patterns are widely employed for protection in several ways. They may make their possessors inconspicuous or they may give to them such grotesque appearances as to frighten away possible enemies. The growls, hisses, barks, and screams of many animals prove to be very effective in scaring away their enemies also.

The development of hibernation, migration, distribution, and complex metamorphoses have all contributed to the perpetuation of animal species.

A defense structure or process is something which adds to the security of an animal, and it usually functions to injure or ward off attacking enemies.

From the structural standpoint, every group of animals in the phylogenetic scheme has its peculiar adaptations for self-

preservation. Even among the one-celled animals some have developed shells (Radiolarians); and others (Paramecium) produce trichocysts which are forcibly discharged and form an effective barrier against aggression by enemy forms. Trichocysts are hair-like strands of protoplasm which form an entanglement, resembling a barbed wire barrier on a battle front, around the section of the animal from which the trichocysts are discharged. The lowly sponges produce skeletal structures called spicules which are needle-like and composed of silicon and limestone, and these are undoubtedly protective. The coelenterates such as hydra, jellyfishes, and sea anemones have highly specialized cells which manufacture stinging hairs or nematocysts. When disturbed, these animals forcibly discharge these hairs which are poisonous and which penetrate the bodies of their adversaries. The nematocysts are really poisoned darts, and with them the coelenterates kill or injure their food victims and their enemies. Large jellyfishes have been known to kill human beings. The smaller jellyfishes that are frequently washed upon the beach should not be handled with the bare hands, for they cause an irritation that is extremely painful.

Among the insects, there are numerous mechanisms which are defensive. They consist of: stings (bees and wasps); biting or piercing mouth parts (ants, water boatmen, assassin bugs, etc.); glandular, poisonous, and penetrating hairs (larva of the *io* moth and the saddle-back caterpillar—*Sibine stimulea*) (Fig. 70); offensive odors (bedbug, stink bugs, whirligig beetles); liquid discharges (caterpillars and the larvae of horntails); gaseous discharges (bombardier beetles); normally hidden structures (scent glands) which protrude when the insect is disturbed (caterpillar of the black swallowtail); protective coloration (leaf mantis, katydid, bark moths, caterpillars); color mimicry (viceroy butterfly) (Fig. 15); body forms which mimic thorns (membracids) (Fig. 18), twigs (larva of brimstone moth (Fig. 16), walking-stick, water scorpion), dead leaves (dead-leaf butterfly), plant galls (spiders, *Euphoria* beetles), and a host of others; grotesque markings (eye spots on the eyed elater beetle and on the owl's-head moth); and a great number of insects feign death.

In the other animal groups there is a diverse assortment of protective devices. Echinoderms (starfish, sea urchin) have tough, spiny skin; mollusks (snails, oysters, mussels, and clams) have hard shells over their soft bodies, while the slugs discharge a slimy

mucus, and the cephalopods (squid and octopus) cloud the water by discharging an inky fluid into it. In the crustaceans such as crabs, lobsters, and crayfishes, the front feet are modified into large and powerful pincers; the myriapods have poison claws (centipedes) and scent glands (millipedes); the arachnids have hollow, needle-like chelicerae, jaws, or poison fangs, through which virulent poisons are injected into their victims and enemies (spiders), or poisonous stings in their tails (scorpions). All of the arthropods have a hard, chitinous body covering or exoskeleton which is in itself a real protection against many enemies, especially in the beetles and larger millipedes.

Among the fishes there are erectile, spinous rays in the fins (catfish, stickleback), in addition to the ability to move rapidly away from danger. Most of them have background colors which make them difficult to see. The porcupine fish has spines all over its body, and these become erect when the animal puffs up. It would be very difficult for an enemy to close its jaws on, or to swallow, a porcupine fish. Toad or puffer fishes enlarge to amazing proportions when captured (also some toads). The tropical eel (South America) is capable of emitting an astounding discharge of electricity in the water; the writer, while wading in the shallow water along the shore of the Cuyuni River in British Guiana, was knocked off his feet when struck by one of these eels.

Green frogs are less visible in grasses, in trees, or among green algae. Tree frogs are protectively colored or change color so as to harmonize with their backgrounds; and the toad has a rough, warty, dirt-colored skin which conceals it on the ground. The toad also possesses skin glands from which it can discharge a slimy, evil-smelling, bitter-tasting, and poisonous fluid when the creature is captured by a predatory animal.

Among the reptiles there are also some unique and interesting methods by which defense is effected. Snakes have sharp, recurved teeth; warning apparatus (rattlesnake); quick movements (black snakes, water snakes, garter snakes); poison fangs (copperhead, coral snake, water moccasin, rattlesnake); and crushing powers (python, boa, pine snake, black snake); often they scare away their enemies by protruding their tongues and shaking their tails. Some snakes issue hissing sounds (cobra, hog-nosed snake) which undoubtedly frighten some enemies. The alligators and crocodiles have powerful jaws and sharp teeth with which they can inflict

serious injuries. The alligator also opens its mouth and violently exhales with an almost bellowing sound. Both the crocodile and the alligator use their tails to slap their enemies. Sleeping alligators and crocodiles also derive some protection from their resemblance to dead logs on the banks of streams. Lizards are usually agile and dart quickly to safety, although all of them can bite. The tropical iguana can bite, scratch, and use its tail as a whip. The writer placed a tamandua or prehensile-tailed anteater in a cage with a large iguana, and the lizard knocked the anteater over every time it got within striking distance. Turtles have hard shells, as a rule; and most of them can seriously injure their enemies by biting them with their horny beaks. Some of the reptiles have offensive body odors which repel many possible enemies. The body scales of reptiles, particularly in turtles and alligators, provide a coat of armor which resists the attacks of most aggressors.

In birds, flight is the chief means of escaping from danger, although many birds rely to a large degree on their background coloration. Many of them, however, have strong bills with which they can inflict painful injuries. Even a chicken or a robin will peck with its bill in a fight, while hawks and owls can inflict serious wounds with their hooked mandibles. An ostrich can kick as hard as a horse, but it kicks forward instead of backward. A number of birds have sharp talons (owls, hawks, eagles) or spurs (game cocks, roosters, and pheasants). Fighting cocks frequently so seriously injure each other that both of the combatants die from the effects of battle. Many birds such as geese can very effectively beat their adversaries with their wings when attacked.

Among the mammals, the protective devices are also diverse. Some of them have: offensive odors (skunks, weasels, peccaries); modified, barbed, penetrating spines (porcupines); coats of armor (armadillo); scratching or cutting claws (cats, bears, sloths, tigers, lions, anteaters); sharp teeth and powerful biting jaws (practically all predators and flesh-eaters); horns and antlers (deer, cattle, rams, moose, elk, bison); cutting hoofs (giraffe, antelopes, deer); powerful kicking legs (horse, rabbit, zebra, cattle); and tusks (walrus, elephant, swine). Many animals travel in herds for safety (cattle, sheep, bison, peccaries). The plain-dwellers (cattle and horses) and mountain sheep and goats usually have a sentinel on guard to watch for approaching enemies while the rest of the herd browses.

Added to these defensive processes there are many self-preserving behaviorisms; and many animals resort to: running away; feigning death; hiding; burrowing; submerging in water; climbing trees; or they depend upon their color for keeping them unseen. Monkeys, snakes, numerous moths, and many birds discharge fecal substances to discourage their attackers or disturbers.

Many animals are nocturnal in their habits because they are safer in the darkness of night, and luminescence is evidently of value only as a protection in many lower forms such as noctiluca, pyrocystis, ctenophores, and jellyfishes.

Animal defense is an interesting counterpart of nature, and its interpretation in all living creatures should be attempted. In fact, the comfort and the safety of the student depend upon a thorough knowledge of the dangerous qualities of the animals he studies. Furthermore, a knowledge of defense contributes much to the understanding of behavior and survival. Numerous defenses, in addition to those mentioned above, will be found in the discussions of the various animal groups.

The Ages of Animals

The life span of animals has always been a matter of conjecture; and fabulous tales have been told about toads entrapped in pockets within rocks for hundreds of years, and which when unearthed by digging or blasting were seemingly in good health. It is interesting to consider the problem of just how long the various species of animals do live under ordinary and extraordinary conditions.

The factors of climate, disease, parasites, parental care, and food all play an important rôle in the longevity of a species. It is very likely that the great majority of organisms in nature meet with a violent death—from combat with their fellows; from predatory enemies; from freezing; by burning to death in forest fires or in volcanic eruptions; by drowning in floods; by being killed by earthquakes or land slides; by tidal waves; from exposure; from parasites; or from disease. It is doubtful if many species reach the age of senility, for as soon as they weaken they become easy victims of all the destructive forces in nature.

While there is much protest against keeping animals in captivity, the fact remains that under proper conditions most wild animals have a greater chance of living for a longer period in captivity than they have when exposed to natural conditions. An animal

in a zoo, for instance, is removed from the disastrous effects of floods, drouths, forest fires, parasites, and powerful killing enemies. Moreover, zoo animals are assured of a regular and sufficient diet which, in nature, is never guaranteed. There are many animals, however, which cannot be kept in captivity at all; and the elephant would probably live longer in the wild state, because it is not always possible to provide bathing pools and other satisfactory conditions. The age data listed here are mostly of specimens kept in captivity, since there are no other means by which the life span of most species can be ascertained. Age characters such as the rings in fish scales, size, skin characters, teeth, vision, and fertility only indicate the present ages of animals, and they do not predict how much longer the species will live. The ear bones are valuable bases for determining the ages of seals and other vertebrate animals.

Many protozoans complete their life cycles in a very short space of time under ideal conditions. Some insects live but a few hours or days. Most insects live for but a single season; but there is an authentic record of a buprestid beetle having lived for 37 years. Many colonial coelenterates grow and increase in size for many years, and the periodical cicada requires almost 17 years to complete its development.

The elephant holds the record among the mammals for living longest, its life being upwards of 100 years. The whale follows a close second with 90 years, although there are tales about whales being 500 years old. Of course humans have exceeded these limits by several years, although the claims of persons who insist that they are as much as 136 years old are to be judged in the light of the uncertainties of memory.

Among the reptiles, the giant tortoise has been known to live for 200 years, and crocodiles and alligators have been kept for from 40 to 100 years. Snakes probably do not live more than 30 years, and the great majority of them considerably less. The potential longevity of frogs and toads is from 12 to 15 years in the frog and as much as 36 years in the toad. In the case of mammals, the larger they are, the longer they live, as a rule. Similar relationships between size and age hold for other animals as well, but not so consistently.

Fishes such as the shark and salmon live to be 100 years old, and the carp 150 years. The birds are the champion long-livers,

however, with many species living more than 100 years. But the list is too long to bear discussion and is given in tabulated form below. However, there are other life phases of animals that command interest. For instance, the elephant is able to breed only once in about two years; the mare once a year; a cow once in nine months; a monkey once in seven months; a sheep once in five months; a dog once in sixty days; the rat once every three weeks; and so on. The duration of the internal development of mammals is known as the period of gestation.

The tabulated material listed below has been secured from numerous sources; and although it is incomplete, it is hoped that it will broaden the knowledge of the student. Rare exceptions to most of these data are matters of common knowledge. For instance, the normal life span of humans is from 70 to 90 years, but a number of people live to be more than 100 years old. The normal number of human young is one; but twins occur rather frequently, especially in family strains, since twinning is an inheritable quality. Triplets and quadruplets occur progressively more seldom than twins, and quintuplets are so unusual as to command world-wide attention.

Thus in all groups, there is an average number of offspring for each species, but maximum and minimum numbers are produced. Likewise, while the period of gestation is definitely established for each species of animal, extensions frequently occur; and even more frequently premature births take place.

In determining the periods of incubation outside the bodies of animals, conditions must be stated; for cold retards, while heat accelerates the development within the egg. The incubation periods of native birds are available in several textbooks of Ornithology.

It is obvious that age is an elastic quality, dependent upon numerous factors over which the individual has little or no control. The life span of species is fairly well established. It has been phylogenetically determined for a given set of conditions but extraneous factors may greatly modify the inherent capacity for living, with which each individual is endowed. Within the species itself, there is often a variation in potential age. While the survival of the fittest obtains, as a general rule in nature, individuals with strong life potentials may be eliminated by fatal accidents.

"How long *will* it live?" is an unanswerable question. "How long *can* it live?" is one to which a fairly accurate and satisfactory answer can be given by the biologist and statistician.

THE MAMMALS

Name of Mammal	Duration of Life (Maximum—Normal)	Normal Period of Gestation	Normal Number of Litter
Man	70–90 years	9 months (280 days)	1
Horse	30 "	12 " (340 ")	1
Cow	20 "	9 " (285 ")	1
Dog	12 "	2 " (63 ")	4–8
Pig	10 "	4 " (118 ")	10–15
Sheep	15 "	5 " (150 ")	1
Rabbit	5 "	1 " (28 ")	4–7
Mouse	18 months	19 days	5–8
Elephant	50–60 years	19 months	1
Cat	12–23 "	63 days	4–8
Rat	3–4 "	23 "	10–11
Deer	20 "	9 months	1–2
Raccoon	12–13 "	63 days	4–6
Skunk	12 "	63 "	4–16
Porcupine	10–12 "	6 months	1
Opossum	7 "	12–13 "	6–13
Bear (black)	20 "	7 "	1–2
Coyote	10–11 "	63 days	5–7
Badger	10–11 "	42 "	2–5
Gray wolf	12 "	63 "	7–9
Bear (grizzly)	20 "	7 months	2–4
Cougar	10 "	97 days	2–4
Lynx	11–12 "	90 "	3–4
Jaguar	20 "	100 "	2–4
Goat	12–14 "	6 months (wild) 5 " (domestic)	1–2
Bengal tiger	25–35 "	4 "	3–5
Rhesus monkey	30 "	7 "	1
Hippopotamus	39–40 "	237 days	1
Llama	17 "	11 months	1–2
Camel (Bactrian)	40 "	409 days	1
Whale	90–100 "	1 year	1
Rhinoceros	40 "	19 months	1
Lemur	31 "	7 "	1
Chimpanzee	31 "	7 "	1
Hare	10 "	5 "	4–8
Guinea pig	6–7 "	3 "	4–8
Squirrel (gray)	6–15 "	6 weeks	4–6
Sea lion	17 "	$10\frac{1}{2}$ months	2
Hyena	14 "	7 "	1–3
Jackal	14 "	63 days	2–4
Fox	14 "	63 "	2–4
Donkey	25–30 "	12 months	1
Zebra	20–30 "	12 "	1
Wild boar	20–25 "	4 "	4–6
Giraffe	19 "	12 "	1
Antelope	17 "	9 "	1–2
Fruit bat	17 "	6 weeks	2–4

BIRDS

Name of Bird	Length of Life (Years)	Name of Bird	Length of Life (Years)
White-headed vulture	100–118	Cassowary	26
Parakeet	120	Skylark	18–30
Parrot	120	Canary	24
Golden eagle	104–150	Peacock	24
Falcon	100–163	Goldfinch	23
Cockatoo	100	Linnit	23
Eider duck	100	Magpie	20
Crow	100	Kiwi	20
Swan	70–100	Nightingale	15–25
Raven	69–100	Turkey	16
Heron	60	Pheasant	15
Goose	50–80	Partridge	15
Duck	50–80	Pigeon	10–20
Ostrich	50	Hen	10–30
Crane	43	Robin	12
Pelican	41	Thrush	10
Seagull	40	Goatsucker	8–9
Dove	40	Swift	8
Sparrow	40	Starling	8
Cuckoo	32	Wren	2–3
Rhea	30		

FISHES AND OTHER ANIMALS

Name of Animal	Duration of Life (Years)—Maximum
Fishes:	
Carp	150
Salmon	100
Shark	100
Eel	60 (Rome Aquarium)
Danube catfish	50
Sturgeon (fresh water)	40
Herring	20
Trout	5–10
Bass	5–8
Sticklebacks	3–4
Minnows	3–4
Amphibians:	
Congo eel	26
Siren	25
Tree toad	22
Toad	36
Frog	12–16
Salamander (Japanese)	52
Newt (Japanese)	25
Newt (Spanish)	20

FISHES AND OTHER ANIMALS—*Continued*

Name of Animal	Duration of Life (Years)—Maximum
Reptiles:	
Giant tortoise	200
Alligator	40
Crocodiles	100
Crustacea:	
Water fleas	2–3
Crab	9
Lobster	9
Crayfish	20

BIBLIOGRAPHY

Ages of Animals

Baumberger, J. P., *Studies in the Longevity of Insects.* Ann. Ent. Soc. Am., 1914.

Beddard, F. L., *Mammalia.* Cambridge Nat. Hist. Series, Macmillan, 1923.

Bronn, H. G., *Thier-Reichs.* C. F. Winter, 1878.

Hammerton, J. S., *Wonders of Animal Life.* Waverly Book Co., Ltd., London, 1929.

Mann, W. M., *Wild Animals in and out of the Zoo.* Smithsn. Inst. Scient. Series, Vol. 6, 1934.

Needham, Joseph, *Chemical Embryology.* Cambridge Univ. Press, 1931.

Roosevelt, T. R., and Heller, Edmund, *Life Histories of African Game Animals.* Scribner, 1914.

CHAPTER V

SOUND: ITS PRODUCTION, PERCEPTION, AND FUNCTION IN THE BIOLOGICAL WORLD

No matter where one wanders in the field, he is received by a chorus of sounds emanating from divers sources. When a stranger invades the realm of wild creatures, his presence is immediately announced by its inhabitants—then all is still. All of these noises, some of which are pleasant and others annoying, contribute to the formation of deep impressions concerning the world of nature. All of them are "calls of the wild" (Fig. 21) and all of them have a real significance in the scheme of life. There are scores of these calls to be heard in any situation. Perhaps it is the bellow of a bull moose as he calls for company; a mother bird calls together her wandering brood; a bullfrog croaks for the benefit of his loved one; a squirrel chirps a warning to his fellows as he scampers away; a cricket sings for its own amusement; a woodpecker drills into a hollow tree; a groundhog digs its burrow; these are but a few of the things one hears and which contribute to the concert in a woodland glade, in an open field, or along the margin of a pond. These constitute "the language of Nature" about which poets write. To understand it is a joyful experience.

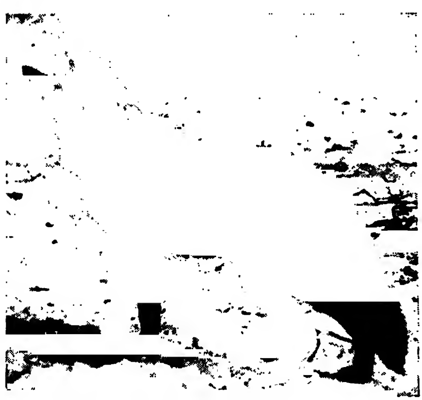


FIG. 21. "The call of the wild." The coyote or prairie wolf. Courtesy Biol. Surv., U. S. Dept. Agric.

There are three important phases of sound to be considered. They are: its production; its perception; and its function. In human society, sound serves as a medium for communication, musical appreciation, warning against danger; and even for emotional expressions, varied as they may be. We humans classify

sounds into two categories: (1) musical sounds and (2) noises. Noise is a social problem today; and while it detracts from the full appreciation of the values of sound, the human capacity for hearing is one of man's greatest blessings.

In the animal world sounds are produced by diverse structures, and in most instances these sounds play important rôles in the lives and loves of those animals with which they are associated.

While there are many creatures which are classified as "silent animals," many of them produce sounds, the vibratory pitch of which is too high or too low for human perception. Just as the human eye is capable of perceiving the light rays in only a small arc of the spectrum, so too the human ear is capable of detecting only vibration frequencies between 20 (vps) and 20,000 (vps).

It has been demonstrated that lower animals may produce and detect frequencies above and below the scope of human audition; and to them, these sounds apparently have a distinct value.

In higher animals such as mammals and birds, sound production and the organs concerned in receiving sound waves are developed to a high degree. In some fishes, the air bladder is at times a sound-producing organ. In frogs and toads, vocal chords are present; but since the amphibia have no diaphragm or ribs, they cannot enlarge the chest cavity. The air is taken into the mouth through the nostrils by lowering the floor of the mouth. Then the nostrils are closed, and the floor of the mouth is raised; this forces the air back through the open glottis into the lungs. The process is reversed in expelling air from the lungs. In male frogs there are vocal sacs in the floor of the mouth on either side, beneath the angles of the jaws. During the mating season these sacs are inflated and act as resonators. Croaking is effected by forcing air back and forth between the mouth cavity and the lungs across the vocal cords. These are two slender bands stretched vertically across the larynx. Observation of a croaking frog will reveal a greatly enlarged throat. The male croak is much louder and of a different tone than that of the female. Croaking is a mating call, and the sexes answer each other. In addition to the mating call, frogs also have a warning call which seems to be a signal to others that danger approaches. A still different sort of cry is emitted when a frog is seized by a snake or other enemy. This is sometimes described as a pain cry.

Among the reptiles, few are noisy. The well-known rattle on the tail of the rattlesnake is the most unique warning signal among reptiles; and it is generally, but not always, used when the snake is disturbed. Some snakes, such as the hog-nosed "adder" or "blowing viper," issue a distinct hissing sound when annoyed. Crocodiles and alligators open their mouths when cornered and forcibly expel air in a hissing manner which is almost a bellow. There is apparently no communication or mating call among reptiles.

Among birds, sound is highly developed and functional. Song is used largely for courtship but the voice is used for various other purposes as well. A great many species of birds have warning calls. When a member of a flock of crows or jays, for instance, detects the approach of danger, it immediately warns its fellows with violent calls which are unmistakable; and the whole flock takes to the wing. When a hawk appears in the neighborhood of a barnyard, the chickens set up a commotion and flee toward safety. Guinea fowl, being capable of louder calls than chickens, are kept by some farmers solely for the purpose of announcing the presence of hawks in the vicinity.

A victorious rooster invariably perches on a fence and issues its "crow of victory" after disposing of his adversary. This habit of announcing success in combat is characteristic of many wild beasts such as wolves, elephants, and lions. It is even indulged in by humans, primitive and civilized. The cheers after winning athletic contests, and the "whoopee" which so frequently announces the winning of almost anything from a bridge game to a coup on the stock market are manifestations of an inner urge on the part of nearly everyone, requiring considerable effort to repress. This urge is a remnant of the primitive "Tarzan call of triumph." Indian hunters employed by the writer in the Amazon jungles invariably issued a shrill, blood-curdling yell after bringing down a wild animal with their arrows. The dance of victory executed by most savage tribes, usually accompanied by yells and the noise of tom-toms and other weird instruments, has its counterpart in parades held by victorious political parties and in the receptions tendered to victorious armies. In these, brass bands and divers noise-making devices play an important part. However, the crowing of a rooster in the morning is a waking call; and although it is not completely understood, it does serve to arouse a sleeping

populace. Not infrequently roosters crow during the night and in some countries the natives attach a significance to this habit. The writer once remarked to an old lady in Mexico about the night crowing of the roosters during the holiday season and her explanation was, "But, Señor, it is Christmas." To some people, the night crow signifies death or some other calamity. However, night crowing usually occurs on bright moonlight nights, which suggests that it is probably a light response. The use of the voice as a means of communication in birds is shown by the fact that a hen calls her chicks, and a rooster may call the hens when he finds a delicious morsel of food which he desires to share with them. A mother bird coaxes her little ones to follow her or she may vehemently protest against disturbance. The ruffed grouse, having no voice with which to attract or serenade a mate, produces the well-known "drumming" by beating the air with its wings. Scratching and pecking are involuntary sounds, and they are usually purposeless except in so far as tapping on the tree trunk with the bill may reveal the hollow burrows of insects upon which the woodpeckers feed.

Many animals have a variety of sounds which are purely emotional expressions. Dogs bark for joy, for food, and to scare away enemies. There are distinct differences in the tones of their barking, too. Anyone who has followed the hounds in the hunt readily recognizes the bark of discovery when a rabbit or a fox is found. Dogs whine and bark to express displeasure or discomfiture. Sometimes they wail when music is played, probably because of the fact that certain vibration frequencies make them miserable. Because of their gregarious nature, dogs call to one another at night. You have noticed that when one dog in the neighborhood barks in the middle of the night, all of the others join in creating a general disturbance. Growling is a sure sign of anger or animosity. Just why a hound will point its nose toward the moon and bay is not definitely known; but it is probably a lonesome call, and it is undoubtedly associated with the mating impulse. It is indulged in by wolves, foxes, and coyotes, all of which are related to the dog. A howler monkey calls the troop together with loud, reverberating howls that send shivers down the spines of humans. This monkey, instead of having a normal hyoid bone or "Adam's apple," has a large, hollow sounding box. Pet and wild monkeys studied by the writer over a period of years showed that they have distinct vocal

expressions for fear, hunger, pleasure, anger, and fatigue. Cats purr when contented, and they squeal and spit when angry. They express their mating desires with a variety of "meows," usually at night. Horses neigh to others and snort when frightened or impatient. A mare will whinny when her colt wanders afar. Mules, burros, and jackasses emit uncanny, communicative calls to others of their kind. The woodchuck is sometimes called a whistle pig because of the noise it makes when angry or frightened. Many rodents chatter their teeth when in a fighting mood. Squirrels chirp when they see an enemy, while lambs and calves bawl or "baa" for their mothers. Bats squeak for communication purposes so that sounds reflected from nearby and unseen objects will guide them in flight. Beavers slap the ground or water with their broad, flat tails to warn other beavers when danger appears. Scores of nocturnal animals call their mates. There seems to be little doubt that animals have lonesome calls or that many of them produce sounds apparently because they like to hear themselves. Even human studies seem to substantiate this conclusion. Then, too, the frequent song of the wren and the nightly outbursts of the yellow-breasted chat and other birds do not seem to be related to survival habits. Animals confined in zoos roar, howl, and wail, apparently for exercise; and much of the crying of human infants is designed for exercise. Some of the smaller spiders stridulate, but the function of the sound is unknown.

While the sounds of higher animals are diverse and interesting, the most remarkable interpretations of sound are to be found in the insects. Insects have no voices and those that do produce sounds have mechanical contrivances known as stridulating organs, as a rule, although sounds are sometimes produced in other ways. The music-making apparatus is as variable as the sounds, their functions, and the manner in which they are detected.

One order, the Orthoptera, stands out among the insects for its musical members. This group, which includes the crickets, katydids, and grasshoppers, is usually referred to as the "singing order." However, many other insects produce sounds for courtship, distress, assembling communication, and for other purposes. Among these are cicadas, larvae of several kinds, bees, ants, wasps, butterflies, moths, flies, tree crickets, termites, and numerous beetles. The "cricket on the hearth" reveals itself by its chirping. The true crickets have no flying wings, but the stiffened wing covers

(tegmina) are provided with a finely toothed area on one wing and a file-like, rasping structure on the other (Fig. 79). By raising and lowering the wing covers, these structures are rubbed together, producing the well-known chirp. The number of chirps per minute is dependent upon the temperature and it has been shown that the chirping increases with a rising temperature. Only male crickets sing, and the song is evidently for purposes of courtship. Sometimes the male accompanies the female on her egg-laying journeys; and he serenades her as she deposits the eggs in the soil. The locusts (short-horned grasshoppers) have a row of very fine teeth on the inner surface of each hind leg. These are rubbed up and down over hardened veins in the tegmina or front wings in a sawing movement. Usually both sexes stridulate and answer each other. The tone of the female is slightly different from that of the male and each sex seems to be able to distinguish that of the other. The various species of locusts can be identified by their songs. In the long-horned grasshoppers (*Acrididae*), the stridulating organs are located at the base of the front wings; and they are brought into contact by the overlapping of the wings. The katydid sings in this way, and its wing covers bulge outward as though inflated with air, thus providing a resonant chamber which intensifies the sound. One native roadside grasshopper (*Dissosteira*) makes a crackling noise in flight by striking the front wings against the hardened anterior margin (costa) of the hind wings. A South American butterfly, *Ageronia*, makes a similar noise in flight. When pursued, it flies noisily for a few seconds, producing sounds like striking two wooden blocks together, and then suddenly drops upon a plant and remains motionless. The writer while collecting these forms was confused by the sudden cessation of the sounds; and this is probably a way in which they throw their enemies off the track.

Many insects, notably bees, wasps, mosquitoes, and flies, make a buzzing sound by vibrating their wings. A honeybee vibrates its wings 440/sec., producing the pitch of A′, and the housefly vibrates its wings 335/sec., producing the pitch of F′. A fly can hum, however, even if its wings are held or detached. This is accomplished by vibrating membranous projections behind the thoracic spiracles. Honeybees and bumble bees seem to express their emotions by changing the pitch of their humming. This is done by changing the vibration frequencies of their wings. You have probably noticed how quickly the intensity and pitch of the

"hum" change when a bumble bee, mud wasp, or honey bee is disturbed.

There are many beetles and some moths (particularly *Sphingidae*) which produce sounds by wing vibrations. The May beetle or "June bug" and other larger beetles have a low vibration frequency; and when they fly close by at night, they sound like miniature airplanes. Many beetles such as whirligigs (*Gyrinidae*), water scavenger beetles (*Hydrophilidae*), milkweed beetles (*Tetraopes*), and other long horns (*Cerambycidae*), and click beetles (*Elateridae*) produce sounds by rubbing the prosternum against the mesosternum. The noise produced is usually a high-pitched squeak or, as in click beetles, a snapping noise. The passalid beetle has two dorsal, abdominal rasps against which the hardened front wings (elytra) are rubbed, while the drugstore or "death watch" beetles (*Ptinidae*) communicate with others by tapping the wood on which they stand with the hardened lower part of the head. Both males and females call each other in this way. Passalid larvae which live within dead recumbent logs can stridulate with their third pair of legs, while other larvae sometimes produce a grating sound by rubbing their chitinous jaws against wood. An African tenebrionid beetle raises its abdomen and lets it fall in quick succession on the hard substratum just as a policeman calls for help by pounding the sidewalk with his stick. Termites which are blind also pound the wood with their chitinous jaws to communicate with others. They keep together in this way.

The cicadas are the champion songsters of the insect world. These insects are found in many parts of the world, especially in tropical regions where their contribution to the concert of animal sounds is certainly distinctive. A commonly heard South American cicada which sings only late in the afternoon has two tones. Sound is produced in the cicada by a highly specialized vibrating organ located on the abdomen at its base. It consists of two shell-like drums, each operated by a special muscle attached to the inner surface. The muscles cause these drums to vibrate rapidly, thus producing the shrill, well-known, extended song. The sound is intensified by two membranes located near the drums. These membranes serve as sounding boards. Only male cicadas sing; as someone has facetiously stated, "The cicada leads a joyful life, because he has a voiceless wife."

Sound production implies its perception and most animals are

equipped with apparatus for recording sounds. On the short-horned grasshoppers the ears are situated on the abdomen. They consist of kidney-shaped membranous tympana or ear drums surrounded by horny rings and located one on each side, just beneath the wings. The katydids and crickets have smooth, elongated tympanal areas on the inner sides of the tibiae of the front legs. Other tympanal structures which are apparently auditory in function are located on the front tibiae of termites and stoneflies. Similar structures are found on the femora of the hind legs on head lice and on the tarsi of some beetles. There are structures, known as sensilla (Johnston's organ), on the antennae of some insects; and these are thought to be auditory. Ants, bees, midge flies, and other insects probably hear in this way. The plumose antennae of male mosquitoes receive, sympathetically, the sound waves produced by the vibration of the thread-like antennae of the females. On caterpillars, adult butterflies and moths, spiders, and flies, there are sensitive hairs which record sounds; while many creatures in contact with the substratum merely receive vibrations through their hardened internal or external skeletons. Just as Indians used to place their ears to the ground to listen for the approach of possible enemies by detecting the vibrations produced by the tread of their feet, so too many subterranean animals such as earthworms, lizards, snakes, insect larvae, and rabbits hear through the ground. Fishes, which are very sensitive to disturbances in water, are thought to hear through delicate nerves attached to the body scales on the lateral line, although an auditory apparatus is also present.

The highly developed internal auditory organs of higher animals are frequently supplemented by external trumpet-like ears to catch sound waves. In many animals (horses, cattle, deer, rabbits) the external ears are movable and can be turned toward the direction of the sound. In birds, of course, external ears would be impedimenta in flight.

One of the most interesting studies in connection with sound is the tabulation of the singing periods of the various noise-making species. Not only can we learn to identify animals by the noises they produce, but we can become familiar with the significance of these sounds and ascertain the time of day or night at which the organisms carry on certain of their activities. Such studies will greatly enrich our appreciation of the world of living things.

From the foregoing account it is evident that sound is an important factor in the lives of animals and that not only do most animals utilize it in some way or another; but they are able to discriminate among sounds and to interpret them in terms of danger, defense, love-making, distress, and communication.

PART II

THE KINDS OF ANIMALS AND WHERE THEY LIVE

CHAPTER VI

THE CLASSIFICATION OF ANIMAL HABITATS

In the study of both animals and plants, it is important to learn the habitat of every species. The thousands of organisms to be found in every locality are distributed according to the variety of conditions or environmental situations present. Many of these organisms are restricted to limited areas within a district. The classification of organisms as aerial, arboreal, terrestrial, subterranean, and aquatic is far too general to allow the interpretations of specific adaptations of selectivities. The aquatic forms, for instance, may be surface dwellers (striders and whirligigs), inhabitants of the bottom trash (libellulid nymphs, toad bugs, bloodworms, etc.), associated with plants (water scorpions, boatmen, backswimmers, aeschnid nymphs), free swimmers (fishes, salamanders), or floaters (plankton animals). Some of them live in still water, while others are to be found only in running water. A hillside spring will harbor animals that are not to be found in the brook that carries away the overflow from the spring. Then, too, the cool, shaded brook will be populated with organisms that could not possibly live in a slow, exposed, meandering creek, or in a pond. Furthermore, the brook inhabitants will not be distributed generally throughout its length; but they will be arranged, geographically, in definite strata in the brook according to rapids, pools, waterfalls; or they will be on the surfaces or under stones; in excavations or along the shore; in collections of débris or free swimming. Some of the organisms in these specific strata are

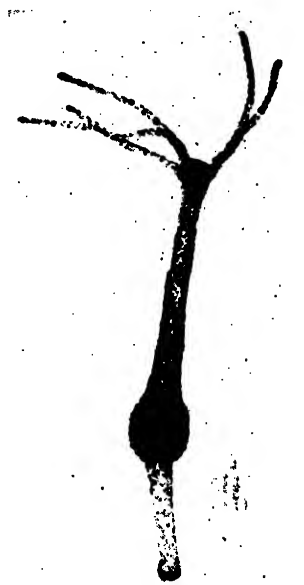


FIG. 22. Hydra, a fresh-water coelenterate (much enlarged).

definitely confined to them and perish if they are transferred to different conditions. Under the discussion of water life, the factors involved in this distribution are explained.

Likewise, the terrestrial organisms may live in woodland areas, open fields, or underground. They may be prairie, desert, marshland, or sand-dune dwellers. They may live in ravines; on hillsides; or among rocks. Some of them are active during the day, while others are strictly nocturnal. Some can tolerate dry soil, while others require considerable moisture. These selectivities apply to plants as well as to animals. For instance, skunk cabbage, ferns, orchids, adder's tongue, and a host of other plants require damp or wet, shady places; while daisies, brown-eyed susans, goldenrods, iron weeds, and the like live in open, exposed fields. Other plants such as mesquite, chaparral, and cacti prefer sandy soil; and they seem to thrive in almost desert conditions where there are long periods of drouth. Many of these plant selections can be observed by the alert student in the yards along city streets in the residential sections.

FIG. 23. A potter wasp and clay nest. From Sanderson and Jackson, *Elementary Entomology*, courtesy Ginn & Co.

Thus it is necessary to clearly and accurately describe the habitats in which organisms are found in order to properly interpret them in terms of environmental conditions. It is obvious that in observing and collecting animals, success depends upon a knowledge of their activities, which may be modified by a host of factors including clouds, sunshine, temperature, season, humidity, time of day, and the presence of the collector.

One of the chief values in habitat study is that the ardent field student soon learns to know where to find particular animals and plants; and he can, after a little field experience, predict what animals and plants will be found in a given situation.

With the hope that it may be of assistance in guiding the student

in making field observations and records, an abbreviated summary of animal habitats is given here.

Each of these situations harbors a set of organisms which is more or less specific for the situation itself. This set of organisms is known as an association, in which there are to be found the plants and animals ordinarily indigenous to that particular kind of situation. For example, there is the dead log association. This comprises a set of animals which can always be expected in a recumbent, decaying trunk of a tree. It includes centipedes, millipedes (mostly *Polydesmidae*), wood lice, spiders, termites, ants, slugs, land snails, engraver beetles, the flattened cucujid beetles, passalid beetles and their larvae, click beetles and their larvae, the wireworms, fungus beetles, larvae of fungus gnats, cockroaches, sowbugs, collembolans, thysanurans; and in hollow spaces there may be toads, skunks, deer mice, salamanders, and other animals which seek shelter

FIG. 24. A crayfish. A. Dorsal view; B. Ventral view.

and safety in crevices. It must not be supposed that all of these forms will be found at the same time. The stages of decay result in a succession of animal inhabitants, and the degree of disintegration will determine the associations to be found at any one time. Then, too, these animals occupy various regions such as on and beneath the bark; in crevices; or in the heart of the wood. But the log or stump presents itself as a definite stratum in which a definite association of animal forms which is characteristic is to be found. Likewise, each of the outer situations mentioned in this abbreviated classification of habitats is also a confined situation, populated by its own specific coterie of individuals. The extensities of habitat studies can be better appreciated by reading Shelford's *Animal Communities in Temperate America*, and *Animal*

Ecology by Pearse. The student of nature should be assigned individual problems of this sort, and an entire class will profit greatly by attacking the local fauna from the standpoint of association studies.

All of the conditions such as locality, specific situation, weather conditions, time of day, and the date should be carefully noted and recorded with each observation or with each specimen collected. This is more important than one might suppose. Such records will develop the ability to find animals more easily, and they will indicate many of the habits of a species including the periods of activity.

The habitats, with suggested examples, are as follows (it is obvious that only a few representatives in each situation can be listed here):

I. Terrestrial animals
   A. Subterranean animals (moles, earthworms, insect larvae, ants, roundworms)
      1. Kinds of soils (clay, sandy, humus, rocky)
         a. Animals that spend all or most of their lives underground (moles, earthworms, roundworms, termites)
         b. Animals that dig for shelter (chipmunks, snakes, toads, gophers, badgers, woodchucks, rats, mice, muskrats, digger wasps, bumble bees, rabbits, carrion beetles, tiger beetles, ant-lions, moths, isopods, crayfishes, social wasps, bank swallows, kingfishers)
         c. Animals that dig for food (skunks, armadillos, badgers, raccoons, opossums, scratching birds)
         d. Cave-dwelling animals (bats, insects, fishes, myriapods, spiders, collembolans)
            (1) Permanent residents of caves (cave crickets, spiders, millipedes, crayfishes, collembolans)
            (2) Transients (bats, bears, foxes, weasels, rats, mice, snakes)
            (3) Aquatic (fishes, crayfishes, worms)
   B. Animals above the surface of the ground
      1. Animals on wet ground (salamanders, frogs, isopods, snails, insects, birds)
      2. Animals on dry sand (spiders, grasshoppers, ant-lions, robber flies, wasps, snakes, lizards)
      3. Animals on medium-dry ground (ground beetles, millipedes, snails, earthworms, mammals, amphibians, insects, birds)
      4. Animals on rocks
         a. Animals in crevices (spiders, snakes, myriapods, salamanders)

b. Animals on the surfaces of rocks (snails, insects, spiders, lizards)
5. Animals on the forest floor (frogs, toads, myriapods, beetles, collembolans, thysanurans, spiders, salamanders, mammals, oven bird, grouse)
6. Animals in neglected, open fields (meadow lark, quail, sparrow, meadow mice, beetles, bugs, spiders, myriapods)
7. Animals on plains or prairies (cattle, coyotes, gophers, badgers, magpies, bison, lizards, toads, spiders, snakes)

C. Desert animals (nocturnal or diurnal)
1. Animals associated with desert plants (insects, scale insects, spiders)
2. Active predators (lizards, snakes)
3. Sedentary predators (ant-lions, spiders)
4. Burrowing animals (kangaroo rats, birds, lizards, ants, spiders)

II. Animals associated with plants (nocturnal or diurnal)

A. Animals associated with trees
1. Animals on the leaves, twigs, flowers, and fruits (aphids, scale insects, beetles, ants, caterpillars, birds, spiders, squirrels)
2. Animals living on the trunks or branches (aphids, moths, beetles, bugs, birds, wasps, bird nests)
3. Animals living in cavities in trees (wrens, woodpeckers, martins, opossums, raccoons)
4. Animals living in the wood of growing trees (wood-boring beetles, larvae of sawflies, carpenter ants, termites)
5. Animals living under the bark (engraver beetles)
6. Animals living in dead wood (centipedes, millipedes, horntails, ichneumons, beetles, and their larvae)

B. Animals associated with shrubs (as above)
1. Animals on leaves, twigs, flowers, and fruits
2. Animals living on the trunk or branches

C. Animals associated with herbaceous plants
1. Animals feeding on leaves (caterpillars, bugs, leaf miners, aphids, beetles)
2. Animals feeding on the flowers and fruits (beetles, moths, butterflies, bugs, bees)
3. Animals hiding in flowers (spiders, thrips, beetles, bugs)
4. Animals living on the stems (aphids, ladybugs, ants, scale insects)
5. Animals living in the stems (ants, gall midges, gall wasps, insect larvae of many kinds)

III. Aerial animals (nocturnal, crepuscular, or diurnal)

A. Passively flying animals
1. Ballooning animals (spiders)
2. Gliding animals (flying squirrels)

B. Actively flying animals
1. Active fliers (bats, birds, insects)

IV. Water animals

(In the determination of life histories and habits it will soon become evident that some aquatic animals are permanent residents of the water; and others spend only a portion of their lives as truly aquatic individuals; while still others are merely occasional visitors to the water.)

A. Animals of flowing water
  1. Animals of rapidly flowing water
    a. Animals of springs (salamanders, crayfishes, fishes, water striders, water sowbugs, May fly nymphs, dragon fly nymphs)
      (1) Animals on the surface of the water (striders, whirligigs)
      (2) Swimming and crawling animals (fish, salamanders, larvae, crustacea)
      (3) Sessile animals (bryozoans, hydra, sponges)
      (4) Burrowing animals (crustaceans, fishes [for breeding], dragon fly nymphs)
    b. Animals of brooks
      (1) Animals on the surface of the water (water striders, floating terrestrial insects)
      (2) Swimming animals (trout, minnows, darters, amphipods, water snakes, salamanders)
      (3) Animals on the stones (flatworms, caddis flies, water pennies, stonefly nymphs, May fly nymphs, eggs of fishes, insects, and salamanders)
      (4) Animals under stones (crayfishes, fishes, hellgrammites, water sowbugs, water snakes, salamanders)
      (5) Burrowing animals (dragon flies, crayfishes, fishes)
      (6) Animals in the rapids (water pennies [Coleoptera], May fly and stonefly nymphs, flatworms, darters, stone rollers)
      (7) Animals in the pools (minnows, water bugs, dytiscid beetles, brook beetles, hydrophilid beetles)
      (8) Animals on the face or at the brink of waterfalls (caddis fly larvae, black fly larvae, stonefly and May fly nymphs)
      (9) Terrestrial visitors (raccoons, muskrats, opossums, otters, snakes)
  2. Animals in slowly flowing water (perch, pickerel, carp, bass, sunfish, catfish, mud puppy, snakes, insects, mussels, snails, caddis fly larvae, horsefly larvae, bloodworms, otters, muskrats, whirligigs, striders)
    a. Animals of creeks
      (1) Animals on the surface (striders, whirligigs, birds)
      (2) Swimming animals (fishes, salamanders, nymphs, crustaceans)

(3) Animals associated with plants (damsel fly nymphs, water bugs, snails)
(4) Plankton animals (daphnia, ostracods, cyclops)
(5) Animals in shallow water and pools along the shore (fishes, brook beetles, salamanders, crayfishes, water bugs)
(6) Bottom animals (catfish, sucker, mussels, nymphs, salamanders, caddis worms)
(7) Terrestrial visitors (spiders, raccoons, snakes, muskrats, marten, fisher, mink, otter)

b. Animals in rivers (all fresh-water fishes, hellbender, necturus, snakes, mussels, snails, insects, otters, muskrats, crayfishes)
(1) Animals on the surface of the water (birds, striders, gyrinids)
(2) Swimming animals (same as with creeks as a rule, but larger fishes such as alligator gar and channel catfish)
(3) Animals associated with plants (insect adults and larvae)
(4) Plankton animals (minute crustaceans)
(5) Animals along the shore: birds (herons, sandpiper, kingfisher, etc.), mammals (otter, mink, raccoon, muskrat, etc.), insects, reptiles, amphibians
(6) Bottom animals (mud puppy, catfish, hellbender)
(7) Terrestrial visitors (mammals, birds, snakes, toads, salamanders)

B. Animals in standing water
1. Animals in lakes and ponds (ponds with sandy bottoms—ponds with muddy bottoms)
a. Animals on the surface of the water (striders, whirligigs, mosquito pupae, collembolans)
b. Animals associated with plants (dragon fly nymphs, damsel fly nymphs, water scorpion, boatman, backswimmer, water measurer, snails, amphipods, egg masses of snails and insects)
c. Animals along the shore
d. Bottom animals (dragon fly nymphs, bloodworms, caddis fly larvae, worms, horsefly larvae, soldier fly larvae, copepods, ostracods, crayfishes, catfish, water sowbugs, mussels)
e. Swimming animals (fishes, salamanders, turtles, snakes, roundworms, beetles, water bugs)
f. Floating animals (plankton, eggs of salamanders, bryozoans)
g. Sessile animals (bryozoans, sponges)
h. Terrestrial visitors (spiders, raccoons, fishes, marten, otter, mink, snakes)

C. Marine animals
1. Animals on the beach (three groups: residents; visitors from

the land; and forms accidentally cast upon the beach by the waves)
   a. Animals on sandy beaches (hermit crabs, worms, beetles, bugs, clams, etc.)
   b. Animals on rocky beaches (octopus, barnacles, snails, etc.)
2. Animals on the beach above water (crabs, spiders, insects, birds, etc.)
   a. Burrowing animals (clams, worms, snails, crabs)
   b. Animals inhabiting shells (crabs, insects, spiders)
3. Animals above high-tide level
4. Animals in the intertidal zone (sand dollars, fiddler crabs, clams, sea urchins, barnacles)
5. Animals in the drift line (jellyfishes, starfishes, brittle stars, sand dollars, sea urchins, sea cucumbers, sponges, corals, numerous mollusks, fishes, crabs, shrimps, amphipods, copepods, isopods, eggs of skates and mollusks, worms, scavenger insects, tiger beetles, sand spiders)
6. Animals in the water
   a. Animals in the shallow water along the shore (fishes, hydroids, clams, crustacea, worms, anemones, ascidians)
   b. Animals in tidewater pools (urchins, starfishes, horseshoe crab, sea cucumbers)
   c. Floating animals (jellyfishes, ctenophores, plankton, copepods, birds)
   d. Sessile animals (barnacles, hydroids, sponges, corals)
   e. Animals swimming near the surface (larvae of crabs and starfishes, dolphins, arrow worm, whales, birds)
   f. Animals in deep water (cetaceans, corals, fishes, ascidians, echinoderms, squids, etc.)
   g. Animals in brackish water at the mouths of creeks or rivers (fishes: herring, flounders, pipefishes, catfish, eels; cetaceans, oysters, ship worms)

V. Animals found on animals (only external parasites are considered here)
   A. Parasitic animals (lice, mites, ticks, fleas, mosquitoes, leeches, horseflies, botflies, bedbugs, sheep tick)
      1. Permanent parasites (lice, bee lice [flies], some mites, strepsiptera, and ticks)
      2. Temporary parasites (mosquitoes, fleas, ticks, mites, bugs, horseflies, black flies, leeches)
   B. Animals living on other animals but not parasitic (sponges on crabs, barnacles on oysters, and fishes attached to sharks)

VI. Animals inhabiting structures made by man (rats, mice, bats, snakes [house, black], pigeons, sparrows, starlings, bedbugs, cockroaches, ants, spiders, sowbugs, skein centipedes, moths, crickets, dermestid beetles, houseflies, fruit flies, mud wasps, fleas, termites, etc.)

CHAPTER VII

THE LIFE IN CAVES

Subterranean caverns have always commanded the interest of people in general and nearly every large cave is associated with tales of pirates, treasure, and gargantuan beasts. The dark recesses have always attracted adventurers who, equipped with chalk, string, whistles, and torches, have tremulously explored them with palpitating hearts and with quickened breath. Foreboding and yet alluring, caves have been mysterious worlds, stirring the imagination of the ages.

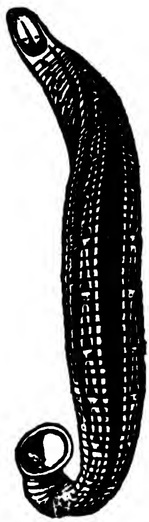


Fig. 25. A leech. After Hegner, *College Zoology*, The Macmillan Company.

Caves have been used by animals and humans since time immemorial. Those of southwestern France have contributed a great deal to our knowledge of the cultures of primitive man. Many animals still utilize the protection offered by caves for hibernation.

In reality the cave is a world in itself with a populace of living things that is unique, diverse, and highly specialized. To the botanist and zoölogist this living world is an entity which presents some interesting problems pertinent to a full understanding of adaptation, distribution, and survival.

There are thousands of caves throughout the world. In the United States they represent time, young and old. Some of them are of comparatively recent origin, while others were in existence long before the last glacial descent. Each type exhibits characteristics which have assisted in determining many of the factors involved in the building up of a cave association; and in the older ones there is a fossil fauna which indicates what animals lived in prehistoric times and how these animals were distributed throughout the world. In Pennsylvania, for instance, the fossil remains of tapirs, peccaries, and ground sloths have been found in caves.

The largest and most spectacular caves of the United States are: the Mammoth Cave in Kentucky, which is ten miles in length and part of a gigantic network of tortuous, subterranean channels extending through a large section of Kentucky, Tennessee, Indiana, and Missouri; Luray Cave in Virginia, another large cavern having around it a great number of smaller caverns picturesque because of the assortment of stalactites and stalagmites found in them; the Shenandoah Valley with its host of smaller caverns; the Wyandotte Cave in Indiana; Carlsbad Cavern in New Mexico; the Port Kennedy Cave in Pennsylvania; and an innumerable number of smaller ones recently discovered because of the public interest in caves.

There are two outstanding physical characteristics of caves; viz., the absence of light and a nearly uniform temperature. It is evident that the first of these conditions has a greater effect upon organisms than the latter. There are three distinct habitat regions within a cave, and each harbors a specific association of animals and plants.

1. **The transition region** (dysphotic) lies at the mouth of the cave, and its limits are determined by the distance to which external light penetrates. This is not a real cavernous habitat, however, since conditions vary considerably with the seasons; and they are largely determined by conditions outside the mouth of the cave.

Bats, nocturnal insects, cave rats, white-footed mice, spiders, owls, toads, snakes, and a host of other animals are to be found in the transitional region, but their presence there is due to a desire on their part to escape the light. Many animals when pursued will seek the safety of a cave. Most of the animals in the transitional region are only temporary residents.

2. **The region of fluctuating temperatures** is usually one of darkness, but in it seasonal fluctuations of temperature are felt. The animals and plants of this region can be found in many smaller caverns and crevices since it is not a truly cavernous realm.

3. **The inner cave region** is an independent stratum where there is a total absence of light and little variation in temperature throughout the year. In some of the larger caves the temperature does not vary one degree during an entire year. In this region there is to be found the unique assortment of plants and animals that can correctly be called the cavernioulous flora and fauna.

In the inner cave region there is considerable moisture, as a rule, although in some sections of the larger caves the dirt is dry and powdery. The cool breezes frequently encountered are the convection currents caused by the flow of water and the descent of breezes from the outside.

Many caves have springs, brooks, or rivers in which there exist a variety of life including fishes, crustaceans, and salamanders. The terrestrial animals include insects such as thysănurans, camel or cave crickets, beetles, and collembolans. All of these, both terrestrial and aquatic, exhibit remarkable adaptations. Most of them are whitish and lack the coloration and countershading which is typical of forms on the surface of the ground. These conditions foster a limited association of animals which exhibit, in general, a curious assortment of adaptive features. A great number of cave inhabitants are eyeless; in many forms which do have eyes, the eyes are rudimentary or vestigial, and they are not functional.

The bodies of cave inhabitants are usually long and slender and the appendages are considerably lengthened as a rule. Since most cave animals are blind and could not see in the stygian darkness even if they did have functional eyes, they must depend upon their other senses for getting about, finding and discriminating among foods, and for defense. The long appendages probably are highly specialized sensory organs and they compensate for the lack of vision.

One of the most remarkable features of cave animals is the modification of the digestive organs. Food is apparently scarce in caves, and the inhabitants have become accustomed to long periods of fast. This naturally implies irregular digestive activity. The organs of digestion have therefore become modified to meet the exigencies of these conditions; and in some forms that have been studied, there is a highly efficient utilization of whatever nutrient the food contains.

The source of cave faunas is of interest. Whence came these strange inhabitants of the dark recesses below the earth's surface? This question cannot be answered in a single statement. Many forms, both plant and animal, are accidental residents derived from epigean ancestors. The aquatic fauna is related to that of the creeks and rivers that flow over the surface of the ground, and they have been swept into these abyssal regions by streams

that disappear into crevices and sinkholes. There are over four thousand sinkholes through which surface waters pass underground in one county in Kentucky. Many of the animals characteristic of subterranean waters have been there for so many years that in each succeeding generation through adaptive response they have become as they are. This is shown by the fact that some of the blind, colorless, caverniculous animals develop eyes and color when reared under normal conditions. However, accidental carrying cannot completely and satisfactorily explain the present animal associations of caves.

There is no doubt that some of the inhabitants are voluntary migrants, having gradually penetrated the dark recesses in successive generations; while many of the animals have probably developed along with the caves. It is also certain that animals accustomed to living without light voluntarily assembled in caves. This is indicated by the fact that most cave-dwellers are feeble-bodied creatures which, because of their lack of adequate defense, originally sought shelter in darkened crevices.

Finally, the absence of suitable habitats probably caused some fossorial animals and animals which normally lived under stones to select caves. The white-footed mouse is an illustration of this secondary selection.

There are many and varied explanations of how the modifications of cave-dwelling animals were effected, but there is one thing obvious: cave-dwellers all conform to a type (light color, long appendages, etc.) due to convergence. Living under a similar set of conditions for a long period of time is conducive to the establishment of a definite type for that set of conditions. This is convergent evolution and is well illustrated by deep-sea life and water life.

As to plants, there is not much to be said. Light is almost essential to all plants and especially to green ones. Consequently there are no green plants in caves. There are a number of fungi including molds and mushroom types. The species and individuals are few, however. One parasitic fungus has been found growing on the bodies of cave crickets.

When caves are accessible, the student of nature should not overlook their possibilities. The life in crevices and in the dark recesses of shale banks and in excavations will exhibit a few characters of subterranean life.

BIBLIOGRAPHY

Caves

Ammen, S. Z., *History and Description of Luray Cave* (3d edition, 48 pp.). J. W. Borst and Co., 1882.

Anonymous, *Report of a Visit to the Luray Cavern in Page County, Va.* Smithsonian Inst. Ann. Rept., 1880, pp. 448–460.

Bailey, Vernon, *Cave Life of Kentucky.* Univ. of Notre Dame Press, 1933.

Banta, A. M., *The Fauna of Mayfield's Cave.* Carnegie Inst. Pub. 67, 1907.

Blatchley, W. S., *Indiana Caves and Their Fauna.* 21st Ann. Rep. Ind. Geol. Nat. Res., 1896.

Call, R. E., "Notes on the Flora and Fauna of Mammoth Cave," *Amer. Nat.*, Vol. 31, 1897, pp. 377–392.

Cope, E. D., *Report on Wyandotte Cave and Its Fauna.* Rept. Geol. Survey of Ind., 1872.

Davis, W. M., *Origin of Limestone Caverns.* Geol. Soc. Am. Bull., Vol. 41, No. 3, 1930.

Eigenmann, C. H., *Cave Vertebrates of America.* Carnegie Inst. Bull., 1907.

Hammerton, J. S., *Blind Fishes, Wonders of Animal Life.* Waverly Book Co., Ltd., London, 1929.

Hovey, Horace C., *Celebrated American Caverns, especially Mammoth, Wyandotte, and Luray.* R. Clarke and Co., Cincinnati, 1882.

——, *Mammoth Cave of Kentucky with an Account of Colossal Caverns.* John P. Morton and Co., Louisville, 1912.

Ives, J. D., *Cave Fauna with Special Reference to Ecological Factors.* Jour. Elisha Mitch Soc., No. 43, 1927.

Jillson, Walter R., *Kentucky State Parks, with Chapters on Mammoth and Carter Caves.* Kent. Geol. Survey, 1927.

Maheu, Jacques, *La flore cavernicole américaine (Grottes de Mammoth Cave et de City Cave, état de Kentucky)*, Bull. Soc. Bot. France 73 ($\frac{1}{2}$): 39–57, 1926.

McGill, Wm. M., *Caverns of Virginia,* Va. Geol. Survey Bull., 35 Ed., Series No. 1, 1933.

McIndoo, N. E., *Notes on Some Arachnids from Ohio Valley Caves.* Biol. Bull., 1911.

Moneymaker, B. C., and others, *Tenn. Aca. Sci. Journal.* Cave Number, Vol. 5, No. 3, 1930.

Owen, Luella Agnes, *Cave Regions of the Ozarks and Black Hills.* The Editor Pub. Co., Cincinnati, 1898.

Packard, A. S., *The Cave Fauna of North America.* Mem. Natl. Acad. Sci., Vol. 4, Part I, 1888.

——, *Cave Fauna of Indiana.* 5th Ann. Report, Peabody Acad. Sci. 1873.

Packard, A. S., and others, "The Mammoth Cave and Its Inhabitants," *Amer. Nat.*, Vol. 5, No. 12, 1871, pp. 739–761.

Packard, A. S., and Putnam, F. W., *The Mammoth Cave and Its Inhabitants*. Ann. Rept., Peabody Acad. Sci. for 1871, Naturalists' Agency, Salem, Mass., 1872.

Pearse, A. S., *Animal Ecology*. McGraw-Hill, 1926.

Putnam, F. W., "Remarks on the Mammoth Cave and Some of the Animals," *Bull. Essex Inst.*, Vol. 6, No. 12, 1874, pp. 191–200.

Randolph, Helen F., *Mammoth Cave and Cave Region of Kentucky*. Standard Printing Co., Louisville, Ky. Contains an excellent bibliography. 1924.

Shelford, V. E., *Animal Communities in Temperate America*. Univ. of Chicago Press, 1913.

Stone, Ralph W., *Pennsylvania Caves*, with a Chapter on Pennsylvania Cave Fauna by C. E. Mohr. Pa. Topog. and Geol. Survey, 4th edition, 1932, Bull. No. G 3 (revised).

——, *Pennsylvania Caves*. Pa. Topog. and Geol. Survey Comm., Bull. No. G 3, 1930.

Weller, Stuart, *Geology of the Princeton Quadrangle*. Kentucky Geol. Survey Series 6, Vol. 10, 1923. An excellent bibliography of data on Mammoth Cave.

Wolf, B., *Animalium Cavernarum Catalogue*. W. Junk, Holland (Den Haag), 1933.

CHAPTER VIII

WATER LIFE: ITS GENERAL CHARACTERS

In every spring, stream, pond, and swamp there abound numerous animals which constitute a comparatively mysterious and unknown, but highly specialized, stratum of living creatures.

A study of the commoner members of the aquatic association will reveal some of the most interesting interrelationships of organisms—plant and animal.

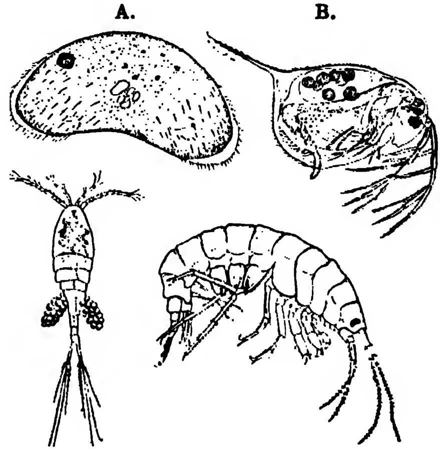


FIG. 26. Small fresh-water crustaceans. A. Cypris (*Ostracoda*); B. Daphina (*Cladocera*); C. Cyclops (*Copepoda*); D. Scud or bender (*Amphipoda*).

In the water are to be found the sources of some of our most spectacular aerial forms as well as the most astounding evidences of convergent evolution.

Just as there is an evident distribution of terrestrial organisms according to soil conditions, amount of shade or sunlight, plant associations, and altitude, so is there a distribution of water life according to depth, movement, turbidity, plants present, dissolved salts and gases, temperature, and bottom conditions. The still pond will have an entirely different set of organisms from that found in a rapid brook. The oceanic plants and animals are on the whole somewhat different from fresh-water organisms although a close relationship exists between them. However, regardless of the aquatic conditions, which are many, it is evident that there are certain general adaptations to aquatic existence to be seen in all water-inhabiting forms. These are the result of the organisms' having been subjected to the same set of conditions for a long period of time during which

they have developed more or less similar adaptive features (convergent evolution).

The first of these general characters is called "stream line form" and refers to the body shape of water animals. It is, mechanically and physically, the most efficient body form for swimming because it offers the least resistance to the water, thus facilitating the swimming of the organisms through a water medium. The fastest swimmers more nearly approach physical perfection in body shape just as the fastest flying birds have body shapes (airline) which enable them to move through the air without offering a surface exposure that would result in great, retarding air pressures against them. The speedy ships are those which cut gracefully and easily through the water without having to overcome too great a resistance of the medium. Another adaptation to aquatic habitation is the absence of external coats, such as hair, which would slow the movement of water animals. The whales and dolphins, which are true mammals and which spend all of their lives in the water, have lost their hair coats in response to an environmental demand. The seals, walruses, otters, minks, and beavers, which are not permanently aquatic, have their hair very much reduced in length. Thus water animals are usually sleek and smooth and frequently covered with a slimy mucus which reduces the friction between their bodies and the water.

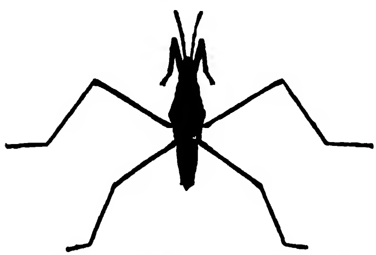


Fig. 27. A water strider or skipper (Hemiptera-*Gerridae*). Courtesy Ill. St. Lab. Nat. Hist.

In what Lull[1] calls "the primarily aquatic animals," which include the fishes, there is also a swim-bladder which regulates the floating powers of the animal.

There are numerous secondary adaptations to a water habitat such as specialized locomotor appendages. These include laterally flattened tails, fin-like appendages, and modified legs.

In the whales, dolphins, and manatees the hind limbs have been lost and the front ones modified into flippers. In the sea turtles the limbs are all paddle-shaped, the front ones being usually elongated and the hind ones reduced (Fig. 194). In sea lizards and alligators the tail (as in fishes) is the chief locomotive organ, and

[1] *Organic Evolution.* The Macmillan Co

it is flattened on the sides. In the flightless penguins the wings have become modified into flipper-like paddles for swimming.

In beavers, otters, and muskrats the feet are webbed for swimming as are the feet of ducks and other swimming birds. The legs of nearly all aquatic insects are modified for swimming.

The external ears and nasal projections of aquatic animals are reduced or absent, and the eyes have shifted their position from the sides toward the top of the head. This enables the hippopotamus, the muskrat, the beaver, the otter, the alligators, and the frogs to rise to the surface, and without exposing their heads, they may "look around" before emerging. In the fishes and amphibia a clear membranous covering, the nictitating membrane, protects the eyes without inhibiting vision.

The whales and dolphins and all other aquatic mammals, as well as the various water-inhabiting reptiles, must come to the surface for air. To facilitate this, the nostrils are on the upper surface, and the cetaceans usually have a single opening or "blow hole." In the manatees or sea cows the nostrils are separate; but as in the cetaceans, they are automatically closed and opened by fleshy plugs. There are numerous other modifications of structures in water animals, such as bones and skin glands, but the foregoing examples illustrate what is meant by aquatic adaptations and should sharpen the ability of the student to identify water animals and interpret them in terms of their environment.

Specific aquatic adaptations are also mentioned in connection with birds, while the major adaptive features of common water animals, especially those adaptations to breathing, locomotion, flotation, and resistance to swift water, will be discussed in the following paragraphs.

The Animals of the Ponds

While the primary objective of the naturalist is to learn to know the more common animals that live in ponds and to become familiar with their adaptations, life histories, and modes of living, it is well to bear in mind that there are many factors which influence the kinds and numbers of animals present in an individual situation.

Conditions in ponds. There are numerous types of ponds: large and small; permanent and temporary; rain-fed and spring-fed; shallow and deep; sheltered and exposed; and ponds of varying

degrees of stagnation and freshness. Each will harbor a more or less unique association of plants and animals, and species found in one pond may be absent from another.

Numerous factors are involved in determining the animals and plants present in any one of the above situations. The amount of free oxygen, carbon dioxide, marsh and other gases, temperature of the water, dissolved salts, source of the water, acidity of the water (hydrogen ion concentration), and the geographical location of the pond are all determining factors in the abundance and diversity of organisms to be found in it.

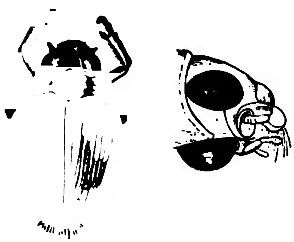


FIG. 28. The whirligig beetle or money bug (*Gyrinidae*). A. Adult; B. Head enlarged to show divided eye. After Snyder, courtesy Gen. Biol. Supply Co.

The differences in the faunal and floral associations will soon become apparent to the persistent investigator; and while the measurement of most of the above factors is a delicate task involving higher chemistry, physics, and sometimes expensive apparatus, the effects of some of them will be quite obvious.

Water insects. Among the water insects there are those which spend the major portions of their lives beneath the surface of the water, and those which are found there only in their larval stages, the adults being aerial. Among the latter are the dragon flies (snake feeders, devil's darning needles), damsel flies, craneflies, horseflies, stoneflies, May flies, dobson flies, midge flies, black flies, and mosquitoes, Figs. 31–33, 35–37. Perhaps of all insects the dragon flies are the best fliers. You have probably seen them dart past with lightning speed and then suddenly stop and remain poised in midair with hardly a noticeable movement of their bodies. On bright summer days the dragon flies may be seen actively foraging

FIG. 29. The fish fly (*Chauliodes serricornis*). After Kellogg, *American Insects*, courtesy Henry Holt and Co.

up and down along the shores of streams, around the margins of ponds; or they may remain over the water far from shore, seldom venturing near it. Some species wander far from the ponds, inhabiting the woods, or flying over dunes and open fields. Every species has its preference for hunting grounds, and each kind has a characteristic flight. The collector soon learns that a different method must be employed for capturing each species. This, of course, adds to the fun of collecting; a real naturalist gets more pleasure from swinging an insect net than he would derive

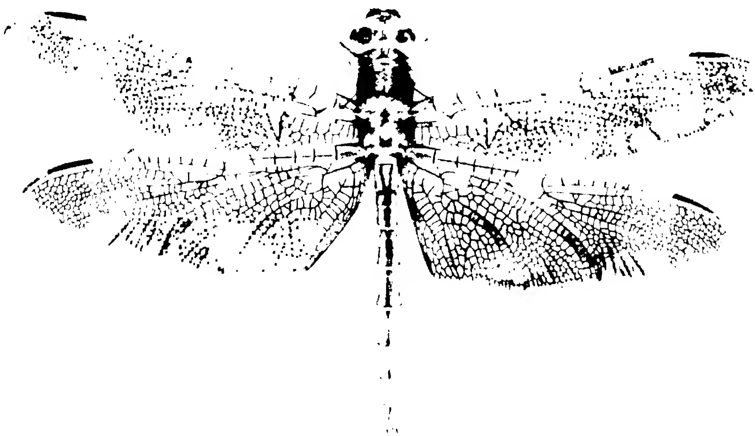


FIG. 30. An amber-wing dragon fly, *Celithemis eponina* (*Libellulidae*).

from swinging a golf club. The dragon fly usually captures its food on the wing; and its legs are so shaped that the captured flies, gnats, and mosquitoes on which it feeds are held in the basket formed by the legs.

The eggs, which are usually laid in the water but sometimes on or in plants, hatch into curiously shaped green or mud-colored nymphs which differ according to species. Some of the nymphs (*Libellulidae*) (Fig. 31) are flat on the underside with the abdomen somewhat rounded. These are mud-colored; and they are generally bottom forms, crawling about in the mud where they feed on larvae of all kinds and even on snails. Other nymphs (*Aeschnidae*) (Fig. 31) are elongated swimming forms which cling to submerged plants and dart after active larvae and small fishes. The nymphs have an extensible labium or lower lip which is armed with

hooks and spines; and when it is withdrawn, it has the appearance of a mask. A quick extension of the labium captures food animals.

The nymphs breathe by means of "rectal gills" which are concealed within the cloacal aperture, and swimming is effected by the ejection of water from the anal opening. The nymphs remain in the water for some time, molting the outer skin from time to time; when mature they leave the water and crawl upon a stone,

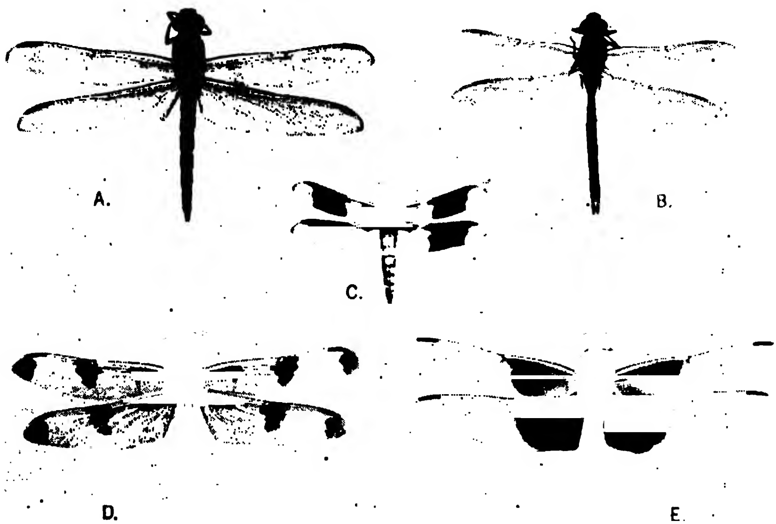


Fig. 31. Common dragon flies. A. *Epiaeschna heros*, female (*Aeschnidae*); B. *Anax junius*, male (*Aeschnidae*); C. *Plathemis lydia*, male (*Libellulidae*); D. *Libellula pulchella*, female (*Libellulidae*); E. *Libellula luctuosa*, male (*Libellulidae*).

log, or plant. The outer skin then dries and splits along the dorsal side. The adult dragon fly slowly wriggles out, unfurls, and vibrates its wings until they are dry, and then takes to the air (Fig. 75), leaving its discarded case or exuvium behind. There are numerous species of dragon flies. Some of them are magnificently colored, and there is frequently a difference between the sexes (*Libellula* or *Plathemis*) (Fig. 31). Mating occurs in midair, and in some species the male attends the female during the egg-laying process. In such cases the two sexes may be seen flying "tandem," the male claspers holding the female "by the neck."

The fact that dragon flies are found where water snakes abound, together with their peculiar methods of laying eggs, has caused

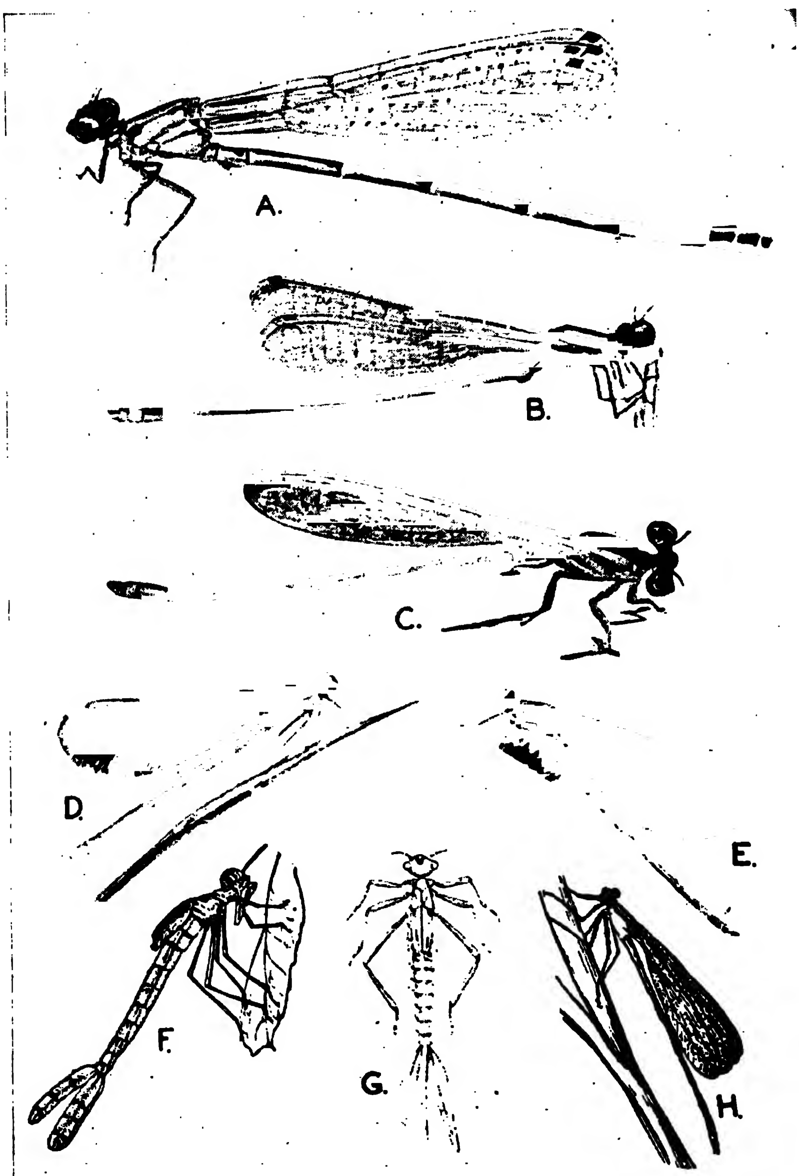


FIG. 32. Damsel flies. A. *Argia;* B. and C. *Enallagma;* D. and E. *Agrion* (*Calopteryx*), female and male; F. and G. nymphs; H. *Lestes rectangularis.* A., B., C., courtesy Ill. State Lab. Nat. Hist.; D., E., courtesy N. Y. State Mus.; F., H., after Lutz, *Fieldbook of Insects,* courtesy G. P. Putnam's Sons.

some imaginative individual to insist that they feed and "doctor" snakes. Dragon flies are harmless creatures, possessing no sting or formidable jaws; and one can handle any species with impunity.

The damsel flies (suborder Zygoptera—"equal wings") are the smaller, more dainty members of the order Odonata. As a rule, their flight is less sustained and at lower altitudes. They may be distinguished from the dragon flies (suborder Anisoptera—"unequal wings") by (1) the wings, which in the latter are of different size and shape, the hind wings being broad at their bases, while in the damsel flies all four wings are about the same; (2) the eyes of dragon flies are large, "glassy," and transparent, and usually (except in gomphines) so close together as to almost touch each other, while in damsel flies the eyes are opaque, globular, and widely separated; and (3) when at rest the dragon fly keeps its wings extended horizontally while the damsel fly folds its wings vertically at an angle of about 45° with the body (Fig. 32).

The life history of the damsel fly is about the same as that of the dragon fly except that the small tapering nymphs (Fig. 32) have three leaf-like gills at the tip of the abdomen. The tracheae ramify through these caudal gills, and their branches receive oxygen from the water through the membranous covering by osmosis.

The most conspicuous dragon flies are; the hoary-bodied *Libellula* which has broad cross bands of brown on the wings, and the large green darner (*Anax junius*) (Fig. 31).

The smoky wings (*Agrion maculata*—Fig. 32), which has a shiny green body and black opaque wings, and frequents small, shaded brooks, is perhaps the most conspicuous damsel fly. The female has less opaque wings with white spots on the anterior margins. Both sexes fly with an erratic, careless sort of flight. The "bluets" (*Enallagma*) are brightly colored forms that fly just above the surface of the water and abound in numbers about ponds. The interested student can readily determine the families and species by using the suggested references.

Hemiptera. There are numbers of the sucking insects to be found in every pond. The most common and widely distributed members of the order are: water boatman (*Corixidae*), back-swimmer (*Notonectidae*), giant and lesser water bugs (*Belostomidae*), water scorpions (*Nepidae*), the toad bugs or crawling water bugs (*Naucoridae*), and the water measurers (*Hydrometridae*) (Fig. 33).

On the surface are the water striders or "skippers" (*Veliidae* and *Gerridae*) (Fig. 27).

One can also generally find very small whitish insects on the water; but these are the primitive wingless terrestrial spring tails (*collembola*), which are not normally aquatic.

The water boatman is a small, brown, flattened, rectangular bug with its last pair of legs quite elongated, the tarsi being broad and flat and resembling oars (Fig. 33). The rowing movements of the oar-shaped legs by which the insect propels itself through the water caused it to be called the boatman. These bugs should be

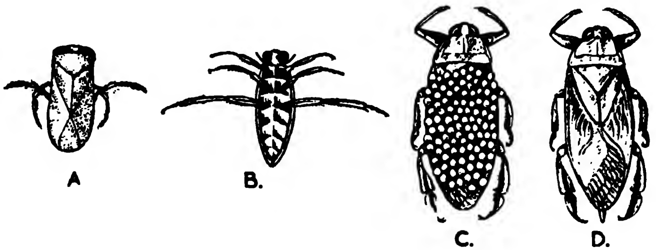


FIG. 33. Water bugs. A. Water boatman (*Corixidae*); B. Backswimmer (*Notonectidae*); C. Water bug, male carrying eggs; D. Giant water bug. (C. and D. *Belostomidae*.) Courtesy Gen. Biol. Supply Co.

handled carefully because they can and do "sting" by pricking the fingers with their needle-like, sucking mouths. They abound among the vegetation near the shore and frequently attach their eggs to the bodies of crawfishes.

The backswimmer has oar-shaped legs, too; but it is a larger, more nearly cylindrical form that swims upside down (Fig. 33). It too can bite, and is found in the same places as the boatman. The nymphal forms of the backswimmer are white, and they have large red eyes. Both the boatman and backswimmer come to the surface for air which they carry down in a film which completely surrounds their bodies, giving them a silvery appearance.

The giant water bug or "electric light" bug is the largest of the hemipterous insects (Fig. 33). It is frequently seen flying around or crawling under street lamps in late summer, which is the only season in which it leaves its water home. In the fresher ponds and in the still pools in creeks, the giant water bug is quite predaceous, attacking salamanders, larvae, snails, and even fishes, killing them by inserting its short, stout, awl-like beak into its victims and sucking their blood.

The lesser water bug has habits similar to the giant water bug, to which it is closely related. The water bug sometimes attaches her eggs to submerged stems, but as a rule she is desirous of depositing them in a safer place. So whenever possible she seizes an unwary male and glues her eggs all over his crossed wings (Fig. 33). The male, being unable to use its wings, must remain in the water until the young hatch.

The wingless young or nymphs immediately seek victims to devour. The water bugs rise in the water and project the tips of their abdomens above the surface for a supply of air which is carried down under the tips of the wings. The water scorpion or water walking-stick (*Ranatra*) (Fig. 34) frequently escapes observation among the plants that are dredged from the pond because it resembles the stem of the plant. The wise student will spread the collected material and carefully watch it until the insect reveals itself by moving its long, spindly legs. The front legs of the water scorpion are adapted to grasping other animals, as are the legs of the giant and lesser water bugs. The animal clings to the upper part of submerged plants, head downward, where it remains inconspicuous and ready to seize passers-by with its front legs. The sharp, sucking mouth is used in killing and eating other animals. On the abdomen are two long, needle-shaped, breathing tubes which are projected above the water when it is necessary for the insect to get more oxygen. The water scorpion is most easily obtained by moving the dip net back and forth among the submerged plants a little distance from the shore.

Another insect, the true water scorpion (*Nepa*) lurks among the muck at the edge of the pond. It is much broader than *Ranatra* and feeds on crustaceans, snails, larvae, and nymphs of damsel flies and May flies.

The crawling water bugs or toad bugs are the thickset, medium-sized insects found in the shallow water near the shore where the vegetation is quite dense. They are also predaceous and bite when handled with the fingers.

The water measurer is a stick-like insect of delicate structure, about one-half inch in length. It has a long, thin body and spindly legs, and is much smaller than the water scorpion which it resembles. It is usually found on floating plants or among the dead reeds along the shore.

The water striders are those surface skippers so familiar to

everyone (Fig. 27). Like the other predatory bugs they have grasping front legs with which they seize insects that fall into the water and suck their juices through a fine, piercing mouth. There are two families of striders, the broad-shouldered and narrow-shouldered forms, all of which make good use of the surface film on water to support them as they "skate" about in search of food.

The water beetles include four principal families of Coleoptera; viz., the crawling water beetles (*Haliplidae*), the predaceous diving beetles (*Dytiscidae*), the water scavenger beetles (*Hydrophilidae*), and the whirligigs (*Gyrinidae*) that live chiefly on the surface.

The crawling water beetles or haliplids are found in ponds, streams, and pools where algae and other aquatic plants abound. They are small (2–5 mm.) convex beetles, usually somewhat yellowish with rows of black punctures on the elytra.

The predaceous water beetles range in size from minute species to the large *Dytiscus harrisi* which is about two inches long (Fig. 39). The dytiscids may be distinguished from other water beetles by the elongated hind legs, which are flattened and fringed with silken hairs for swimming, and by their *thread-like* antennae. Their bodies are less convex than those of the scavengers, and the middle and hind legs are far apart.

Among certain species there are distinct sexual differences, the female having deep longitudinal furrows on the elytra, while the wings of the males are smooth. The males usually have cup-like suckers on the front feet or tarsi which enable them to hold the female during coition. None of the dytiscids are brilliantly colored, and most of them are brownish black and shining. Some species have yellow markings, especially a yellow band around the margin of the elytra. The eggs are laid in punctures made in plants; and the larvae, which are called water tigers, are quite predaceous, attacking fishes, tadpoles, and other insects (Fig. 39). The larva breathes through tubular spiracles located on the tip of the abdomen, and it rises to the surface thrusting the spiracles into the air. When mature, the larva leaves the water and burrows in the ground where it pupates. The smaller species of dytiscids are always present in every pond, where they may be secured by dipping out the vegetation that grows on the bottom. When the net is drawn, the dytiscids may be quickly identified by their jumping movements. In the *Dytiscidae* the hind legs are thrust backwards simultaneously, while in the *Hydrophilidae* the legs alternate.

The whirligigs, "money bugs," "perfume bugs," or gyrinids usually congregate in numbers on the still pools in a sluggish stream, and their gyrating movements are familiar to everyone (Fig. 28). The gyrinids are almost elliptical in form, slightly convex, and bluish black with a bronze luster above. The front legs are rather long and slender, while the middle and hind legs are quite short, broad, and flattened, making excellent swimming organs. The whirligigs can move with remarkable speed; and when disturbed they zig-zag rapidly out of the way or dive under the surface of the water where they are covered with a film of air that gives them a silvery appearance.

Fig. 34. The water scorpion, *Ranatra americana* (*Nepidae*). After Osborn from Metcalf and Flint, *Fundamentals of Insect Life*, courtesy McGraw-Hill Book Co.

The whirligigs emit a milky fluid when captured. In the larger species the odor of the fluid is not unpleasant, but in the smaller forms it is quite offensive. These odors prevent their being eaten by birds and fishes.

Inasmuch as the insects are subject to dangers from fishes below and from birds and bats above, the eyes are completely divided by the margin of the head, the under pair being adapted to looking into the water and the other pair adapted to looking through the air (Fig. 28).

The whirligigs lay their small, cylindrical eggs in rows on the leaves of water lilies and other plants. The larvae are long, narrow, and quite flat, resembling young centipedes. When the larva is full grown, it leaves the water and spins a gray cocoon which is attached to some object close to the water. The pupal stage lasts about one month.

The water scavengers or hydrophilids are extremely common among the plants in ponds. They are elliptical, black beetles which may be distinguished from the dytiscids by their club-shaped antennae, crawling legs, and long palpi. They are also considerably more convex than the dytiscids, and they do not have the elongated hind legs. The hydrophilids carry a bubble of air on the underside of the body. The eggs are usually enclosed in peculiarly shaped cocoons which are attached to the undersides of floating leaves (Fig. 38), although in some cases the

cocoons are attached to floats, while in others the cocoon is carried about by the female. Although the hydrophilids are supposed to be vegetable feeders, they frequently eat other insects; and as the eggs hatch, the stronger larvae occasionally eat their companions. The larvae of the hydrophilids are somewhat similar to dytiscid larvae; but they are stouter, and their jaws are not so prominent (Fig. 38). There are many species of hydrophilids ranging in size from very small forms to the large *Hydrous triangularis* which

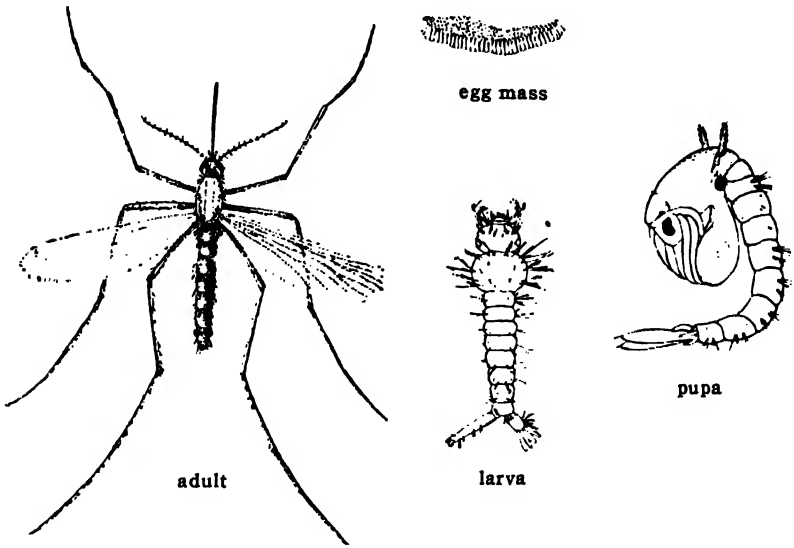


FIG. 35. Life history of the mosquito (*Culicidae*). Courtesy Gen. Biol. Supply Co.

measures nearly two inches (Fig. 38). The commonest species is of moderate size (one-half inch).

It would be impossible for anyone but an experienced student of insects to distinguish the many species of water beetles, but every student should be able to distinguish the four families. In most cases this is not difficult to do; and the works of Hatch, Metcalf, Brues and Melander, Bradley, Comstock, and Blatchley are recommended for determining families, genera, and species.

Another beetle, the adult of which is not aquatic, is the leaf beetle (*Donacia*), which is usually abundant on the upper surfaces of the larger floating leaves such as those of the water lily. These are long, horned, elongated beetles with a variable coloration of

green, bronze, and purple. The under surface is brown and hairy. The holes in the water-lily pads are made by females which eat through the leaves and then insert the tips of their abdomens through the openings. The egg clusters are white and conspicuous; and when the eggs hatch, the larvae descend to the stems where they bore in and feed on the tissues of the plants and where they subsist on the air contained in the stems. The leaf beetles belong to the family *Chrysomelidae*, to which belong also the potato beetle, asparagus beetle, and the striped cucumber beetle of the gardens. The leaf beetle has a relative that is also found on lily pads but which does not have any aquatic stages. This species (*Galerucella nymphaea*) has indistinctly striped wing covers and lays masses of small yellow eggs on the surface of the leaf. The larvae resemble, in a way, the larvae of "ladybugs."

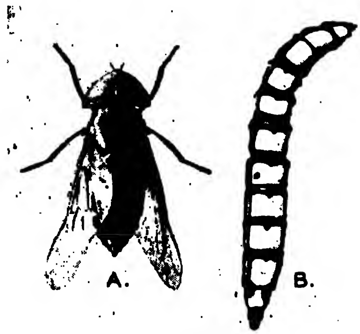


FIG. 36. A horsefly (*Tabanus atratus*). A. Adult; B. Larva. After Metcalf and Flint, *Fundamentals of Insect Life*, courtesy McGraw-Hill Book Co.

Among the two-winged insects (order Diptera) that live in water are: craneflies (*Tipulidae*), mosquitoes (*Culicidae*), horseflies (*Tabanidae*), soldier flies (*Stratiomyiidae*), midge flies (*Chironomidae*), Syrphus flies (*Syrphidae*), and black flies (*Simuliidae*). Of these the mosquitoes, horseflies, and midge flies are more characteristic of ponds, while the others are generally found in streams. In almost all of the above groups there are certain species that live in ponds while others are found only in streams.

The common mosquitoes all lay their eggs in raft-like clusters which float on the surface of the water (Fig. 35). All rain barrels and pools are good collecting places for eggs, pupae, and larvae. The eggs hatch into the well-known "wrigglers" which swim by looping their bodies. Breathing of the larva is effected through gills attached to breathing tubes (tracheae) on the abdomen; and the larva must go to the surface and thrust these tubes above the surface for air. When a film of oil is spread on the surface of the water, the larvae cannot reach the air and they suffocate.

The pupa of the mosquito is active and swims by means of a

leaf-like structure on the tip of the abdomen. While there is a strong resemblance between the larva and pupa, the latter can be easily distinguished by the greatly swollen head and thorax. The breathing tubes are on the dorsal surface of the thorax of the pupa; so the pupa rests with the upper side of the thorax just beneath the surface film, while the larva rests at the surface with the head downward and the tip of the abdomen at the surface. The swollen thorax gives buoyancy to the pupa, which takes no food; and when the pupa is mature, the skin splits along the back; and the imago or adult mosquito emerges. The newly emerged adult stands on its pupal case, which serves as a raft; and when the wings are dried, it takes to the air. There are pronounced differences between the sexes of adult mosquitoes, the male having plumose antennae while those of the female are thread-like. Only the females suck blood, the males feeding mainly on plant juices.

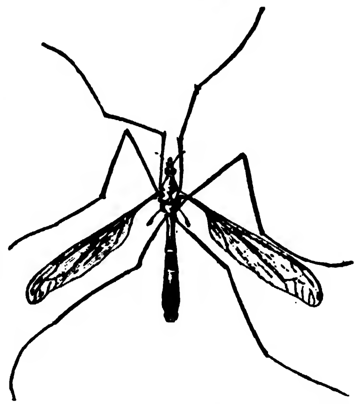


FIG. 37. The giant cranefly (*Tipulidae*). After Kellogg, *American Insects*, courtesy Henry Holt and Co.

Mosquitoes are nocturnal, but they are not equipped with nocturnal eyes. Nor do they have scent glands by means of which the sexes can find each other. Instead, they have a remarkable radio system with a sending or receiving apparatus by which the meeting of males and females is effected. During the mating season the female vibrates her thread-like antennae producing sounds of extremely high pitch (frequency). At this time, too, the male holds his plumose antennae (which constitute the "receiving set") erect; and these receive sympathetically the vibrations of the female, and in this way he is guided to her. It is the same principle of sympathetic vibrations that causes certain objects in a room to rattle when a particular key on the piano is struck.

The horseflies constitute a group of blood-sucking flies that breed mainly in water. The fleshy larvae (Fig. 36) are found among the bottom trash in stagnant water close to the shore. The two commonest species are the large, uniformly black morning fly (*Tabanus atratus*) (Fig. 36) and the pestiferous *Chrysops*

niger which is a medium-sized species which attacks man as well as cattle. It has a brownish body with yellow markings and prominently closed eyes. The wings have cross bands of brown. Only the females are parasitic.

The soldier flies are usually flower insects and are so named because of brilliant stripes which occur in many species. The eggs of some of the species are laid in the water, and the larva is one of the most peculiar of the dipterous insects. It is spindle-shaped and stiff, with a plume of bristles on the slender end of the body. It is called the rat-tailed maggot.

The craneflies are large flies that look like giant mosquitoes (Fig. 37). They are found during the day on the vegetation in damp woods and along streams. The eggs are laid in water by the female which strikes the surface of the water with the tip of the abdomen in much the same manner as do certain dragon flies. The eggs hatch into worm-like, soft-bodied larvae which become quite large.

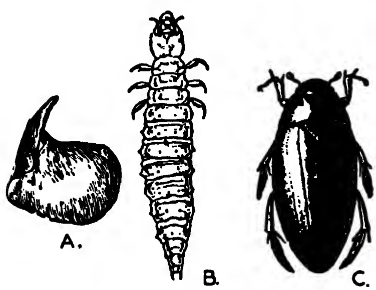


Fig. 38. The large water scavenger beetle (*Hydrophilus triangularis*). A. Egg case; B. Larva; C. Adult. From Lutz, *Fieldbook of Insects*, courtesy G. P. Putnam's Sons.

At the posterior end of the body is a cluster of fleshy lobes (6–8) which constitute the spiracular disc within the center of which are the spiracles through which the insect breathes. As in nearly all fly larvae, the mouth is poorly developed, the eyes are absent, and there are no external appendages.

The midge flies are mosquito-like flies, the males of which have conspicuous plumose antennae. The midges are abundant in all climes and along the Great Lakes at certain seasons they almost cover the low vegetation, arising in great swarms when disturbed. As a rule the midges are harmless, although the "punkies" or "no-see-ums" of the northern states and Canada can be quite offensive. Some species of midges breed in swift waters, others in stagnant pools, and some kinds in large lakes.

The larvae are long, slender, worm-like creatures with fleshy prolegs at both ends of their bodies. Some species surround themselves with fragile tubes of dirt; some are slender, whitish worms; while others stand erect on the muddy bottom and wave their

bodies to and fro. These are the red "bloodworms" which every collector finds in his dip net full of muck. They are very slender and measure almost an inch in length. They breathe by means of two pairs of long, thin-walled sacs on the eleventh body segment. These sacs are known as blood gills. The pupae are also aquatic and the pupal cases serve as floats for the newly emerged adults.

The syrphid flies or bee flies are usually terrestrial (Fig. 17); but one common species (*Eristalis tenax*) breeds in the decaying vegetation in shallow, stagnant water. The larva has a long, tail-like air tube which can be held above the surface when the body is completely submerged. It is almost one-half inch long and is also called the "rat-tail maggot."

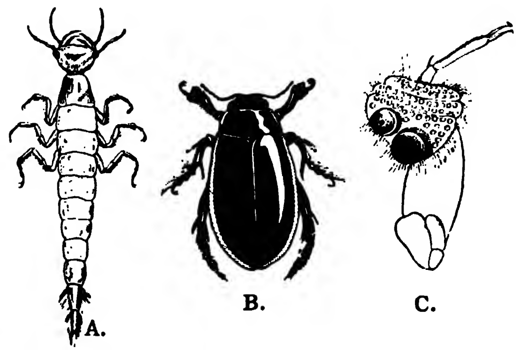


Fig. 39. The predaceous diving beetle (*Dytiscus marginatus*). A. Larva, the water tiger; B. Adult; C. Front tarsus of male showing discs for holding female. C. after Folsom.

The *Lepidoptera*, too, have a few aquatic representatives, the commonest of them being the lily leaf caterpillar (*Nymphula maculalis*), which lives within a case made of two pieces of leaf about one inch long and one-half inch wide. These pieces are secured together by silken threads. The larva lives within the case, which affords it protection from predatory enemies and makes it necessary for it to expose only its head which can be quickly withdrawn. The larva has numerous bushy thread-gills on its sides, and these extract air from the water which surrounds the insect within the case.

The adult has grayish front wings with irregular darker markings. The hind wings are white. The moths fly about over the water in the twilight hours and rest on the marginal vegetation during the brighter part of the day.

Crustacea. The pond representatives of this class include the crayfish and a number of its very small relatives. Some of them, like the crayfishes, are widely distributed geographically and ecologically. While those listed here are chiefly pond inhab-

itants, they may also be found in lakes, rivers, and sluggish streams.

When the "catch" in a pond is placed in jars or tanks, some of these small forms such as cypris (*Ostracoda*) and cyclops (*Copepoda*) will distribute themselves on the sides, while others such as daphnia (*Cladocera*) will migrate back and forth and rise and descend in the water.

Cyclops (Fig. 26), daphnia (Fig. 26), and cypris are all sometimes called water fleas. Cypris is about the size of a pinhead; and

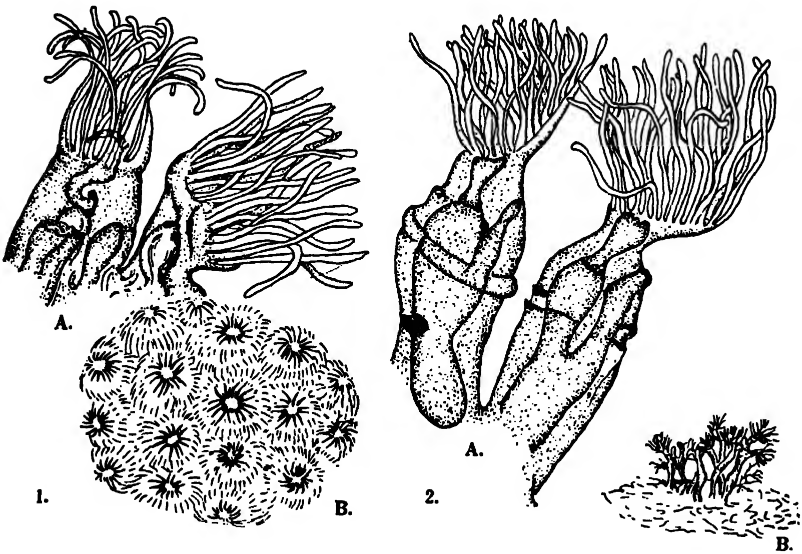


FIG. 40. Fresh-water bryozoans. 1. *Pectinatella;* 2. *Plumatella.* A. Individual animals; B. Habit. Courtesy Gen. Biol. Supply Co.

when examined with a magnifier, it is seen to be clam-shaped, and its outer "crusty" skeleton is composed of two valves which are hinged at the back, just as in clams. These tiny crustacea abound among green algae and other submerged plants to which they attach their eggs. They feed chiefly on plant material.

Cyclopia are minute, tapering crustaceans which can be found in every ditch or pool among algae and ditch weeds. They feed on microscopic organisms and decaying vegetation. The females carry their eggs in sacs located on the sides. There are several common genera of copepods some of which are whitish and others red, blue, or purple.

Daphnia is one of numerous cladocerans which infest fresh waters. It is raised by fish culturists as food for "guppies" and other aquarium fishes. The largest of the cladocerans is *Leptodora* which is a common inhabitant of the Great Lakes. It is half an inch long. There are several common species which may be taken in fresh-water ponds by dragging a fine net through the water. The magnifier reveals ten legs and a transparent body case through which the digestive organs can be seen. No student should fail to observe the living daphnia when it is so accessible.

FIG. 41. A black fly or buffalo gnat (*Simuliidae*). After Kellogg, *American Insects*, courtesy Henry Holt and Co.

All of these minute forms lay two different kinds of eggs. The summer eggs which are held in brood pouches have thin shells and develop rapidly without being fertilized (parthenogenesis), while the autumn eggs have heavier shells and are fertilized. The latter are the resting eggs which remain over winter. All of the smaller crustacea serve to sustain the fish population since they constitute the chief food of the young of several commercial species of fishes. Some of them are also known to be the intermediate hosts of parasitic worms which infest higher animals.

The water sowbug differs from its land cousin the pill bug in body shape, which is more slender in the aquatic form. It is a dull gray in color and has seven pairs of legs. Water sowbugs are usually bottom forms, and they are abundant in the muck where they feed on organic material. The common forms belong to the family *Asellidae*, and they are frequently found under stones and along the shores of small streams. The egg pouch is carried on the underside of the thorax.

The scuds or benders (Fig. 26) are larger than the water fleas, and they are equipped with more specialized appendages. The bender can move with rapidity through the water, usually swimming on its side. The body is arched or bent, and each segment has a pair of biramous appendages. The legs on the thorax enable the animal to cling to and climb over water plants, while the appendages on the abdominal segments are adapted to swimming and jumping. The largest of the common amphipods is *Gammarus* which attains a length of an inch, the female being the larger. The food consists of decaying animal and vegetable matter and myriads

of both common genera *Hyallella* and *Gammarus* may be taken in any pond or stream. They mate from early spring until late in the fall, and the eggs are carried in brood pouches on the thorax.

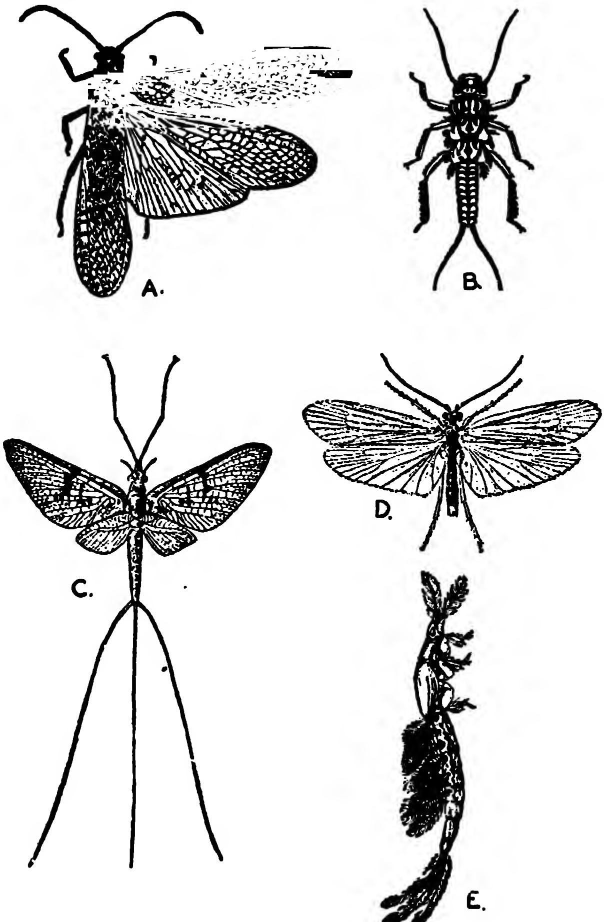


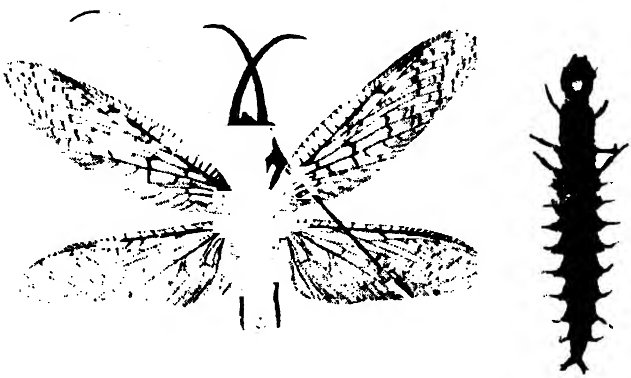
FIG. 42. The stonefly, May fly, and caddis fly. A. Adult stonefly; B. Nymph; C. Adult May fly; D. Adult caddis fly; E. May fly nymph. A. and E. from Hegner, *Invertebrate Zoology*, A. after Comstock; C. and D. from Lutz, *Fieldbook of Insects*, courtesy G. P. Putnam's Sons.

The fairy shrimp (*Phyllopoda*) is the largest of the smaller crustaceans (*Entomostraca*) and is an inch in length. The appendages are peculiar, fringed, leaf-like structures which are quite conspicuous. Each segment of the thorax carries a pair of these

appendages which are used as swimming and respiratory organs. The fairy shrimp swims on its back and feeds on microörganisms which are captured and passed to the mouth by its "gill-feet."

Females are more numerous than males; and as in daphnia, they breed parthenogenetically until late fall when males develop. The males differ from the females in that the antennae are modified for clasping the female during coition. As in the crayfish there are also modified appendages on the males for use in transferring the spermatozoa to the female.

Arachnida. In addition to the insects and crustaceans, the arachnids also have representatives in the pond association. The



A. B.

FIG. 43. The dobson fly (*Corydalus cornutus*). A. Adult male; B. Larva (hellgrammite).

tiny red water mites can be found at all seasons in every pond, where they feed on small animals.

The mites lay their eggs on plants or on the mantles of mussels as well as on the bodies of insects. Water striders are usually infested with numerous red larvae of mites, and the eggs are also frequently seen on the upper surface of the last few abdominal segments of adult damsel flies. The mites range in size from very minute forms to the large *Hydrachna* which is almost as large as a pea.

The diving spider is another arachnid inhabitant of ponds; but unfortunately its most interesting structure—its nest—is not seen. When the dip net is lifted, one often sees spiders scampering away. Where do they come from? Are they typical members of the pond

association? They look so sleek and dry, and yet they must have been dredged from the water. While they are not truly aquatic animals, the diving spiders are part of the water fauna, contributing their part to the drama of life staged beneath the surface of many ponds. This interesting spider descends into the water on the stem of a submerged plant. Its hairy body holds a film of air around it, giving it a silvery appearance. Sometimes the European species constructs a bell-shaped nest under water; and by introducing bubbles of air into it, the water is forced out, enabling it to live and lay eggs within its "caisson." The diving spider feeds on water insects and their larvae. It belongs to the family of running spiders or wolf spiders, *Lycosidae*. A number of running spiders utilize the surface film and venture out onto the surfaces of ponds where they feed upon floating insects.

Worms. While there are some small (usually microscopic) aquatic oligochaete relatives of the earthworm, the principal and most widely distributed annelid worms that exist in fresh water are the leeches. These are predatory or parasitic worms with thirty-four segments and with anterior and posterior suckers. They abound in ponds and small lakes where they are parasitic on frogs, salamanders, and turtles. They attack man, and one common species known as the medicinal leech (*Hirudo medicinalis*) (Fig. 25) is frequently used by physicians in removing blood clots. The old-time drugstore always kept a bowl of living leeches for emergencies. The leeches attach themselves by the oral end, and with bristle-like, chitinous structures they make an incision through which they suck blood. An anti-coagulating substance is present in the saliva and prevents a stoppage of the blood flow. A leech can ingest more than its own weight of blood which is stored in eleven or more pairs of branched stomach pouches on the alimentary tract. It can live for a year or more on a single meal. The largest of the common leeches is deeply pigmented with green and yellow.

Leeches are hermaphroditic and carry their whitish eggs and young on the underside of the body. Swimming is effected by looping and by undulating the body. Crawling is effected by alternate attachment of the oral and distal or posterior suckers.

Bryozoa. On the submerged logs and stones and occasionally floating in quiet waters there may frequently be seen jelly-like masses of various sizes. These are colonies of "moss animals" or

Bryozoa. Each colony may contain hundreds of picturesque individuals, all compacted together forming an almost transparent, gelatinous, irregular mass. When examined with a magnifier, the individual animals or zoöids may be distinguished. These resemble the flower-like animals in a coelenterate colony. The size, shape, color, and covering of the colony are dependent upon the species involved and upon diverse factors of the environment. The colonies are usually sessile, but in a few common forms there is an ability to migrate for short distances.

There are three rather common Bryozoans: (1) *Plumatella*, a small, branching colony found in ponds and streams; (2) *Cristatella*, a small (2–5 cm.) elongated colony found frequently on the undersides of water-lily pads; and (3) *Pectinatella* which is the largest and most conspicuous of all eastern forms. *Plumatella* and *Pectinatella* are shown in Fig. 40.

Animals in Running Water

It has been indicated that the faunal association of a pond is regulated by numerous physical and chemical factors. A number of these same factors are also determiners of the animal life to be

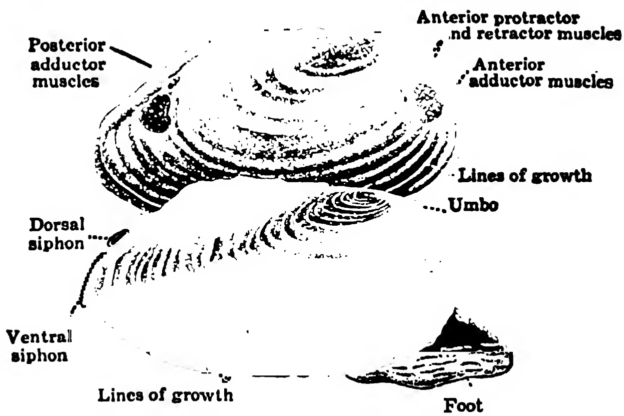


FIG. 44. External features of a mussel. After Shipley and MacBride from Hegner, *College Zoology.*

found in running water, together with several additional conditions which do not apply to bodies of still water. For instance, the rapid brook will have in it some animals that are not inhabitants of sluggish creeks. Nor will the small, shallow, narrow creeks have some of the larger animals which can be found only in rivers. On

the other hand, even the most rapid stream will have small side pools and back-water sections wherein some animals which are characteristic of still waters may exist.

Within the stream itself there are numerous situations, each with its unique set of animal forms; and while the following list suggests the more common types of stream animals, it must not be supposed that all of them will be found in every part of the stream or that all of them will be found even in the same stream. Some of them are surface animals. Others live among the trash in the shallows along the shore. Some live on the brink or face of waterfalls, and others inhabit the pools at their bases. There are those which can be found only in the ripples, usually on the leeward sides or undersides of rocks or in excavations or depressions on the bottom. There is also a unique geographical distribution of these individuals with range limits for each. There are distinct southern, northern, eastern, and western types; and the animals in a mountain stream will be different from the faunal association in the lowland streams. Therefore, if all of the organisms found in every aquatic situation were listed here, we would see an overlapping of faunae in all of them. For example, May flies are found in ponds and in very rapid brooks; but they are different species of May flies.

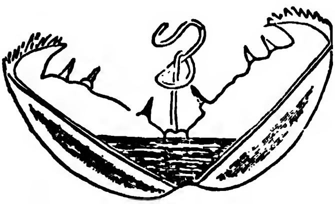


FIG. 45. A larval mussel or glochidium (greatly enlarged). After Lefevre and Curtis from Hegner, *Invertebrate Zoology*.

Since in this treatise we are not interested in particular species, May flies in general are discussed. Such a marked similarity exists among May fly larvae (nymphs, naiads) that the student who learns to know the May fly nymph he finds in a rapid brook will not fail to identify those immature stages of May flies when he finds them in a pond. While the nymphs of some May flies live in ponds, they were not listed among the pond animals because they are typically characteristic of the life in the rapid brook.

Just as frogs, water scorpions, and painted turtles are typical animals of standing water, so are the stoneflies, May flies, caddis flies, dobson flies, fish flies or alderflies, black flies, flatworms, and crayfishes prominent animals of running water. To these may be added numerous fishes such as darters, blobs, trout, chubs, shiners, carp, and bass, and also salamanders such as hellbenders and mud

puppies. These animals are all found in running water—rivers, creeks, or rapid brooks.

Plecoptera. The adults of stoneflies are winged, aerial insects which rest by day on the vegetation along the streams. They are short-lived and not easily obtained in numbers unless one sweeps the foliage of plants or attracts them to lights at night. The eggs are laid in running water, and the young are called nymphs or naiads. Many of these nymphs, particularly the members of the family *Perlidae*, are rather brightly colored with yellow and black. They are found on stones in swift water where they are well

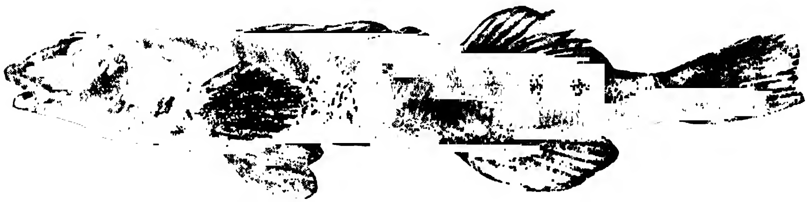


FIG. 46. The log-perch infested with the parasitic larvae or glochidia of a fresh-water mussel.

adapted to resisting the current. Their bodies are flat, thus offering little surface to the rushing water; and their thin, flattened, clinging legs enable them to crouch close to the stones. The feet are equipped with two claws which help them to crawl about and to "hold on." When one lifts the stones in a stream, the nymphs scoot to the underside with the dripping water and drop off. The nymphs remain in the water for a year or more, feeding on vegetable matter and occasionally on other insects. After a series of molts, the nymph becomes mature. It then crawls out of the water onto the elevated and exposed stones, and the adult emerges through a dorsal split in the skin. The adult has four wings, the hinder pair being folded together under the front pair which lie, one on the other, straight along the back when at rest (Fig. 42).

The stonefly nymph may easily be distinguished from the May fly nymph by three outstanding characters: (1) the foot has two claws; (2) there are two divergent cerci or tail filaments; and (3) the tufts of thread-like gills are on the underside of the body at the bases of the legs and most conspicuous on the thorax, although in some species they are more prominent on the neck. There are only two families of stoneflies. The commonest species belong to the following genera and families: *Perla* (*Perlidae*), with

prominent gills at the bases of all legs; the large, brownish *Pteronarchys* (*Pteronarcidae*), with gills also on the first two abdominal segments; and the short, stout, blackish *Peltoperla* (*Perlidae*), in

Fig. 47. Fresh-water mussels. 1. and 2. *Eurynia recta*, male and female; 3. and 3A. *Truncilla sp.*; 4. and 4A. *Alasmidonta sp.*; 5. *Margaritana sp.* After Ortmann, *Mem. Carnegie Mus.*

which the gills are concealed under the margins of the broad thorax. A few species have no gills at all.

Ephemerida. The May fly nymphs occur in the rapid sections of streams and differ from stoneflies in that they have (1) filamentous gills (seven pairs) conspicuously located on the sides of the abdomen; (2) the foot has only one claw; and (3) they usually have three tail filaments (Fig. 42). The habits of the May flies are extremely diverse, and modifications of the important features in-

dicate the various species. They are found in ponds, along the shores of streams, in the swiftest rush of current, or in burrows.

The adults of May flies are among the most unusual and interesting insects in the world. The "dance of the May flies" is a marvelous spectacle. Thousands of them, mostly males, dance over the surface of the water in a mating ceremony, rising and descending in their flight, after which the males die immediately, and the females settle on the water and proceed to lay their eggs.

There are several outstanding, one might say astounding, characters which make the May flies interesting objects for study. In the first place, they have two pairs of eyes (divided eyes), one pair which is adapted to nocturnal vision and the other pair to diurnal vision. Furthermore, the May fly has a most unusual life history. The eggs, which frequently have peculiar structures which enable them to float, are laid in the water and hatch into the nymphal forms mentioned above. When maturity is reached after a number of molts, they crawl out of the water and split along the dorsal side. But the form that emerges is not a true adult as in the case of stoneflies and all other winged insects. Instead it is a "subimago" fully winged but not yet mature. These gray-winged forms fly to the foliage of trees and shrubs where they molt again, the new forms with darkened wing veins being mature.

In the May flies the mouth parts are degenerate; and the adults, which live only from a few hours to a day, never feed. The alimentary tract is filled with air and inflated which makes possible the first flight by adding to the buoyancy of the insect. This is the only instance among all of our native winged insects where the creature molts again after acquiring wings.

One large species of May fly (*Hexagemia bilineata*) is called the "Canadian sailor" by persons living along the Great Lakes, where on occasions hundreds of thousands of them are attracted to the lights of city streets at night. Frequently they are so numerous as to completely cover store fronts, and their dead bodies fall in heaps beneath the lamps. This is a large species, the nymphs of which live on the bottom of the lake beyond the breakers. When the nymph is mature, its air-filled case rises to the surface where it floats. The adult emerges through a slit in the back, and the emerged insect uses its exuvium as a raft until it is able to fly. The idea that May flies fly across the lake from Canada is of course an

erroneous one. There is one principal family of May flies, *Ephemeridae*, in which there are several subfamilies.

Neuroptera. Under the stones in the rather swift section of the stream lives a reddish- or brownish-colored, long, formidable-looking larva which is the delight of bass fishermen. It is called a "hellgrammite"; and it is a nocturnal predator, feeding on larvae, small fish, and other animals which it catches at night. This larva, which is three inches long, has three well-developed jaws and three pairs of well-developed legs on the thorax. Each abdominal segment has a pair of lateral appendages at the bases of which are tufts of whitish hairs. There is also a pair of prolegs, one on each side of the anus. These are equipped with hooks by means of which the animal is able to "hold on."

After living in the water for almost three years (two years and eleven months) the larva leaves its watery home and crawls under a stone or log near the shore, and pupates. After several weeks the winged adult or dobson fly emerges; and except for the large gray wings, the adult greatly resembles the larva. The body is soft and ill-smelling; and the male (Fig. 43) has long, curved, formidable-looking jaws which are used only to hold the female while mating. The adults, which are frequently attracted to lights in summer, never feed and probably do not live more than twenty-four hours. The female after mating lays her eggs on the foliage overhanging the water. There may be several thousand eggs in a cluster an inch wide. When the young hatch, they drop into the water in which they spend the major portion of their lives. The dobson fly belongs to the order Neuroptera, family *Corydalidae.*

Another related insect, the alder fly or fish fly (family *Sialidae*) (Fig. 29), has a larva similar to that of the dobson fly, but it is much smaller and lacks the gill tufts so characteristic of the hellgrammite. The fish fly larva is usually found in quiet water.

The sialid fly (*Sialis infumata*) is another aquatic neuropterous insect which is quite common and widely distributed.

Coleoptera. There are many types of beetle larvae from "glow worms" to "grubs," but the water penny is the most curious of all. It is a stone-colored, almost rounded, slightly convex, disc-like larva, almost as large as a dime. Almost any slightly cold, rapid brook will reveal numbers of them clinging to the undersides or to the downstream sides of stones, their flattened bodies adhering so tightly that they are difficult to dislodge with the finger nail.

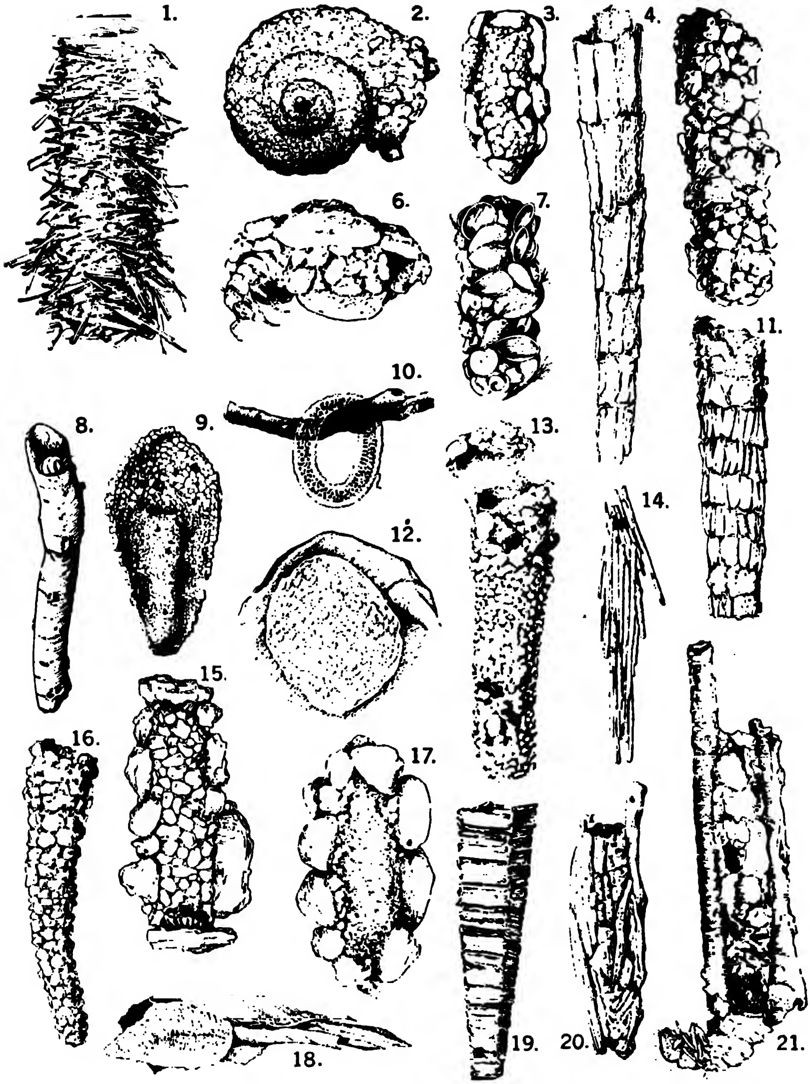


Plate I. Types of caddis fly cases. 1. *Platycentropus;* 2. *Helicopsyche borealis;* 3. *Neophylax sp.* (pupal case); 4. *Neuronia sp.;* 5. Pupal case of a limnephilid; 6. Larva of *Mystrophora americana;* 7. *Limnephilus rhombicus;* 8. *Ganonema nigrum;* 9. *Molanna sp.;* 10. Egg ring of *Phryganea;* 11. *Phryganea sp.;* 12. Egg cluster of *Hydropsyche;* 13. *Hesperophylax designatus;* 14. *Anabolia bimaculata;* 15. Pupal case of *Neophylax* with membrane ruptured; 16. *Psilotreta frontalis;* 17. Pupa of *Hydropsyche sp.;* 18. One type of larval case of *Arctoecia consocia;* 19. *Brachycentris nigrosoma;* 20. *Astenophylax argus;* 21. Larva of *Stenophylax luculentus.* After Betten, Bull. 292 N. Y. State Mus.

These are the young of brook beetles (*Parnidae*) which live nearer the shore. The water penny breathes by means of five pairs of conspicuous white gills which, with the legs, are only visible when the creature is turned over. It pupates on the stones in water, covering itself with a silky coat. The yellow eggs are attached to stones in the swiftest part of the stream.

Trichoptera. The caddis flies, like the May flies, have representatives in ponds as well as in streams; but they are so numerous in rapid brooks that they may almost be considered as the dominant insects. There are several kinds of common "caddis worms," as the larvae are called; and each species builds and lives within its own particular kind of case which it frequently carries about with it. The most common of these cases consists of an irregular, tubular mass of sand and fine gravel cemented together and glued fast to the undersides of stones in the rapid water. The larva has a blackish head and thorax, and the abdomen is greenish. Other species make cylindrical cases, about the diameter of a lead pencil, composed of small sections of stems and sand glued together. These are usually pond forms. Some caddis larvae use sections of hollow stems; others construct straight or coiled tubes of sand; another fastens two broad leaves together; and one species that lives in very rapid water makes a silken cup-shaped net between the sides of crevices or between two stones. The net faces upstream and serves to strain food from the water as it passes through. It also makes it unnecessary for the larvae to expose itself to the rush of water and be swept downstream. Some cases are shown in Plate I.

The larva holds itself within the case by means of hooks on the hind end of the body. Tubercular protrusions on the sides provide ample space for water to circulate around the body. The gills are always filamentous and usually located on the sides.

The larva pupates within its case and provides for its safety by spinning a net over the open end of the tube. This keeps out enemies but allows water to enter, and air is absorbed through the pupal gills.

The adult is a small, aerial, moth-like insect with wings covered with fine and often brilliantly colored hairs. The antennae are long, being in some cases several times as long as the insect. Caddis flies are nocturnal and short-lived. They lay their eggs in various water situations, gluing them to submerged objects or depositing them in small green rings which are placed on water plants.

Diptera. The black fly larvae (*Simuliidae*) are found on the surfaces of stones in very rapid water. Sometimes they completely cover the face of a waterfall where thousands of individuals are so compactly assembled as to make the rocks have a black and slippery surface. They are very small, blackish, worm-like larvae which hold fast to the rocks by means of a sucking disc at the hind end of the body. Standing almost on end, the mouth end is free to gather diatoms with the fan-shaped collecting brushes located at the oral end.

Just back of the head is a fleshy proleg which also has a sucker on it, and by alternately attaching the two suckers the animal is able to move about over the stones in the swiftest waters. To secure itself in the rushing water, the larva anchors its body with a thread spun from the mouth. Using this thread the animal is able to travel downstream. The larva breathes through three rectractile blood gills on the posterior end of the body. The pupa is enclosed in a yellowish cocoon, and in midsummer these cocoons transform the rocks from black to golden. The pupa breathes through fringed tracheal gills on the upper end of the pupal case.

The adults are the small black flies which are active along streams in the daytime; and certain northern species are miserable pests, biting both man and beast.

Crustacea. The crayfish, crawfish, or "crab" (Fig. 24) is a familiar animal to everybody. While some species are found in ponds, there are others called chimney builders which are burrowing species. These live in low, moist regions or in mud flats where they dig down to the ground water. The mud is carried to the surface and is piled up around the open hole, or well, forming a chimney. Deep in the ground the animal constructs a series of branching tunnels with widened sections or pockets in which it may be found by digging.

The common crayfish is typically an animal of the stream in which it forages by night, remaining in an excavation beneath a stone during the day. Where the water is swift the animal escapes the rush of current by resting in an excavation on the bottom.

The crayfish feeds on soft-bodied animals such as fishes, larvae, and snails. It is also a scavenger and helps to reduce pollution of the water by removing dead matter.

During the day the crayfish can be found under stones where it rests with its antennae or "feelers" extended and with its chelae or

"pincers" in a position of defense. At night it crawls about over the bottom in search of animals on which it feeds. The large chelae seize and tear apart the food; and with the assistance of the mouth appendages and the front legs, they transfer it to the mouth where the hard mandibles bite off portions of it. The food passes into the stomach where three opposing, chitinous teeth constitute a "gastric mill" in which mastication takes place.

In order to fully appreciate the habits of crayfishes it is well to study the gen ral anatomical features. The animal has numerous appendages, most of which are biramous and arranged in series on the various body segments. These appendages are highly modified and specially adapted to performing different functions.

The body, which is covered with a hard, outer shell or skeleton composed of chitin and lime, consists of two main regions. The head and thorax are fused together into a *cephalothorax* to which the more slender, segmented *abdomen* is attached. On the anterior end of the cephalothorax are two pairs of antennae or feelers. One pair is long, while the shorter pair, called the *antennules*, is branched. At the base of the antennules are small whitish cup-like structures called the *statocysts* in which there are sensitive hairs. These structures are apparently organs of equilibrium since grains of sand are embedded in the hairs and serve as statoliths. When iron filings are substituted for the grains of sand and a magnet suspended over the animal, it immediately turns over.

The eyes are on stalks which fit into grooves when the animal is relaxed; but when danger approaches, the stalks are extended so that a larger field of vision is obtained. The eyes are compound and composed of numerous smaller eyes, resembling in a way the insect eye.

The mouth is under the head slightly anterior to the very first pair of legs. It is surrounded by the mandibles, maxillae, and three pairs of maxillipeds which are the obvious leg-like structures around the mouth.

The crayfish has five pairs of legs, all of which are attached to the thoracic region. The first pair of legs or chelipeds is modified into pincers or chelae with which the animal captures food and defends itself. They do not serve as legs but are used for excavating burrows in addition to the above uses. When the crayfish loses one of its pincers, it regenerates the lost part; and one often

finds individuals having one large and one small pincer. The other four pairs of legs are the walking legs, and the second and third pairs have little pincers on them which are also used in picking up and transferring food to the mouth. The covering of the thorax is called the *carapace*, and it has flexible flaps (branchiostegites) on the sides so that the water may be forced under it into the branchial chamber where the gills are located.

Each abdominal segment has a pair of flattened, biramous appendages called pleopods or swimmerets. On the male the first pair of swimmerets have the branches fused together, forming rods which are used to transfer the sperm to the female. On the female the first pair of swimmerets is considerably reduced. The sixth and last segment bears the tail which consists of three separate short broad segments used for swimming.

The female attaches her eggs to the swimmerets and carries them about with her until they hatch; and the young remain attached to the parent for several days, as a rule.

Probably because they are predatory and equipped with formidable weapons of offense, crayfishes frequently engage in combat, fighting bitterly until one of the contestants is vanquished.

Crayfishes are miniature fresh-water editions of lobsters and they are edible—in fact, quite palatable. In Europe they are used extensively as food. Crayfishes, like spiders, are capable of removing injured or captured parts, which are soon regenerated. This practice of self-mutilation is known as *autotomy*.

Other stream animals are discussed in the chapters on Amphibia, Reptiles, and Fishes.

BIBLIOGRAPHY

Crustacea [1]

Borradaille, A., and Potts, F. A., *The Invertebrata*. Macmillan, 1932.

Calman, W. T., *The Life of Crustacea*. Macmillan, 1911.

Carpenter, G. H., *On the Relationships between the Classes of Arthropoda*. Proc. Royal Fish Acad., Vol. 24, 1903.

Clark, A. H., *Animals of Land and Sea*. Van Nostrand, 1927.

Creaser, E. P., *Decapod Crustaceans of Wisconsin*. Trans. Wisc. Acad. Sci., Arts, Let., No. 27, 1932.

[1] Because of the abundance of crustaceans in fresh water situations it seemed advisable to create a separate bibliography for them.

Creaser, E. P., *The Phyllopoda of Michigan.* Mich. Acad. Sci., Arts, Let., No. 11, 1930.

Dodds, G. S., *A Key to the Entomostraca of Colorado.* Univ. Col. Stud., Vol. II, No. 4, 1915.

Embody, G. C., *Distribution, Food, and Reproductive Capacity of Some Fresh-water Amphipods.* International Revue der gesamten Hydrobiologie und Hydrographie, Biol. Suppl. No. 3, 1912.

——, *Crustacea—A Key to the Common Genera Occurring in the Fresh Waters of Eastern United States.* Cornell Univ. Studies, 1914.

Forbes, E. B., *A Contribution to a Knowledge of North American Fresh-water Cyclopidae.* Bull. Ill. State Lab., Nat. Hist. Vol. 5, 1897.

Fordyce, Charles, *The Cladocera of Nebraska.* Univ. Neb. Zoöl. Lab. Bull. 42, 1901.

Fowler, H. W., *The Crustacea of New Jersey.* N. J. State Mus. Ann. Rep., 1911.

Harris, J. A., *An Ecological Catalogue of the Crayfishes Belonging to the Genus Cambarus.* Kan. Univ. Sci. Bull., Vol. 2, 1913, pp. 51–187.

Hay, W. P., *Crustacea of the State of Indiana.* Proc. Ind. Acad. Science, 1896.

——, *Life History of the Blue Crab.* U. S. Bur. Fish. Rept., 1905.

Hegner, R. W., *Invertebrate Zoölogy.* Macmillan, 1933.

——, *The Parade of the Animal Kingdom.* Macmillan, 1935.

Herrick, C. L., *Final Report on the Crustacea of Minnesota Included in the Orders Cladocera and Copepoda.* Minn. Geol. and Nat. Hist. Surv., 12th Ann. Rept., Part 5, 1901.

Herrick, C. L., and Turner, C. H., *Synopsis of the Entomostraca of Minnesota.* Minn. Geol. and Nat. Hist. Surv., 2d Rept. State Zoölogist, 1895.

Herrick, F. H., *Natural History of the American Lobster.* Bull. Bur. Fish., Vol. 29, 1909.

Holmes, S. J., "Synopsis of the Amphipoda," *Amer. Nat.*, Vol. 37, 1903.

——, *The Amphipoda of Southern New England.* Bull. Bur. Fish., Vol. XXIV, 1904.

Hyatt, Alpheus, *Worms and Crustacea.* Bos. Soc. of Nat. Hist. Guides for Science Teaching, Vol. 2, 1897.

Juday, C., *Diurnal Movement of Plankton Crustacea.* Trans. Wisc. Acad. Sci., Arts, Let., Vol. XIV, 1904, pp. 524–568.

Kingsley, J. S., "The Classification of the Arthropoda," *Amer. Nat.*, Vol. 28, 1894, pp. 118–120.

Kunkel, B. W., *The Arthrostraca of Connecticut.* Conn. Geol. and Nat. Hist. Surv. Bull. 26, 1918.

——, *The Selective Actions of Certain Adverse Environmental Conditions on the Hermit Crab.* Carnegie Inst. Tortugus Lab., Vol. 28, 1934.

Marsh, C. D., *A Revision of the North American Species of Cyclops.* Trans. Wisc. Acad. Sci., Arts, Let., Vol. 16, 1907.

Morgan, Ann, *Fieldbook of Ponds and Streams.* Putnam, 1930.

Needham, J. G., and Lloyd, J. T., *Life of Inland Waters.* Comstock Pub. Co., 1916.

Needham, J. G., and Needham, Paul R., *Guide to Fresh-water Biology.* Amer. Viewpoint Soc., Inc., 1927.

Ortman, A. E., *The Crawfishes of the State of Pennsylvania.* Mem. Carnegie Mus., Vol. 2, 1906.

Packard, A. S., *Phyllopod Crustacea of North America.* 12th Ann. Rep. of U. S. Geol. Surv., Vol. I, 1883.

Paulmeier, F. P., *Higher Crustacea of New York City.* Bull. 91, N. Y. State Mus., 1905.

Pearse, A. S., "Fresh-water Copepoda of Massachusetts," *Amer. Nat.*, Vol. 40, 1906.

——, *The Crawfishes of Michigan.* Mich. Geol. and Biol. Surv. Pub., Biol. Ser. No. 1. 1910.

——, *Notes on Phyllopod Crustacea.* 14th Rep. Mich. Acad. Sci., 1913, pp. 191–197.

Pilsbry, H. A., *Sessile Barnacles.* U. S. Nat. Mus. Bull. 93, 1916.

Pratt, H. S., *A Manual of the Common Invertebrate Animals.* A. G. Mc-Clurg Co., 1929.

Rathbun, Mary J., *List of the Crustacea.* Papers Boston Soc. Nat. Hist., VII, 1905.

——, *The Fauna of New England.* Occ. Papers Boston Soc. Nat. Hist., 1905.

——, *The Spider Crabs of America.* U. S. Nat. Mus. Bull. 129, 1905.

——, *The Grapsoid Crabs of America.* U. S. Nat. Mus. Bull. 97, 1917.

——, *The Cancriod Crabs of America.* U. S. Nat. Mus. Bull. 152, 1929.

Rathbun, R., *Natural History of Economic Crustaceans.* U. S. Comm. of Fish and Fisheries, Doc. 224, 1893.

Richardson, Hamet, *A Monograph of the Isopods of North America.* U. S. Nat. Mus. Bull. 54, 1905.

Schacht, F. W., *The North American Centropagidae.* Bull. Ill. State Lab., Nat. Hist., Vol. 5, 1898.

——, *The North American Species of Diaptomus.* Bull. Ill. State Lab., Nat. Hist., Vol. 5, 1898.

Sharpe, R. W., *Contributions to a Knowledge of the North American Fresh-water Ostracoda Included in the Families Cytheridae and Cyprididae.* Bull. Ill. State Lab. Nat. Hist., Vol. 4, 1897.

——, *Report on the Fresh-water Ostracoda of the United States.* Proc. U. S. Nat. Mus., Vol. 26, 1903.

Sharpe, R. W., *A Further Report on the Ostracoda of the United States.* Proc. U. S. Nat. Mus., Vol. 35, 1908.

Shoemaker, C. R., *Amphipods of the Family Bateidae in the Collection of the United States National Museum.* Proc. U. S. Nat. Mus., Vol. 68, 1927.

Smallwood, M. E., *The Beach Flea.* Cold Spring Harbor Monographs, 1903.

Smith, S. I., *The Stalk-eyed Crustaceans of the Atlantic Coast.* Trans. Conn. Acad., Vol. 5, 1878 to 1882, pp. 27–138.

Turner, C. H., *Additional Notes on the Cladocera and Ostracoda of Cincinnati, Ohio.* Bull. Sci. Lab. Denison Univ., Vol. 8, 1893, Part 1, pp. 1–18.

——, *Crayfishes of Ohio.* Ohio State Univ. Bull., Vol. 30, 1926.

Ward, H. B., and Whipple, G. C., *Fresh-water Biology.* John Wiley and Sons, 1918.

Weckel, Ada L., *The Fresh-water Amphipoda of North America.* Proc. U. S. Nat. Mus., Vol. 32, 1907.

Wilson, C. B., *The Copepods of the Woods Hole Region.* Smith. Inst. U. S. Nat. Mus. Bull. 158, 1932.

Water Life

Adams, C. C., *A Guide to the Study of Animal Ecology.* Macmillan, 1913.

Bamford, M. E., *My Land and Water Friends.* Lothrop Co., 1886.

Barnes, T. C., and John, T. L., "Properties of Water of Biological Interest," *Quart. Rev. Biol.*, Vol. 9, 1934.

Bassler, R. S., *The Bryozoa or Moss Animals.* Pub. 2633 Smithson. Rep. for 1920.

Bere, R., *Leeches from the Lakes of Northeastern Wisconsin.* Trans. Wisc. Acad. Sci., Arts, Let., No. 26, 1931.

Birge, E. A., *A Second Report on Limnological Apparatus.* Trans. Wisc. Acad. Sci., Arts, Let., No. 20, 1922.

Birge, E. A., and Juday, C., *A Limnological Study of the Finger Lakes of New York.* Bull. 32, U. S. Bur. Fisheries, 1914.

——, *The Inland Lakes of Wisconsin.* Wisc. Geol. and Nat. Hist. Surv. Bull. 27, 1914.

——, *Further Limnological Observations on the Finger Lakes of New York.* Bull. U. S. Bur. Fisheries No. 37, 1921.

Bishop, S. C., and Clarke, N. T., *A Scientific Survey of Turner's Lake, Isle-on-Haut, Maine.* N. Y. State Mus., 1922.

Carpenter, K. E., *Life in Inland Waters.* Macmillan, 1928.

Clemens, W. A., *Limnology of Lake Nipigon.* U. of Toronto Biol. Studies 22, 1923.

Davenport, C. B., *Report on the Freshwater Bryozoa of the United States.* Proc. U. S. Nat. Mus., Vol. 37, 1904.

Denniston, R. H., *A Survey of the Larger Aquatic Plants of Lake Mendota.* Trans. Wis. Acad. Sci., Arts, Let., No. 20, 1922.

Eggeling, Otto, *The Freshwater Aquarium and Its Inhabitants.* Henry Holt, 1908.

Fassett, N. C., *The Plants of Some Northeastern Wisconsin Lakes.* Trans. Wisc. Acad. Sci., Arts, Let., No. 25, 1930.

Fish, C. J., *A Preliminary Report on the Coöperative Survey of Lake Erie.* Bull. Buffalo Soc. Nat. Sci. No. 14, 1929.

Forbes, S. A., *The Biological Survey of a River System, Its Objects, Methods, and Results.* Bull. Ill. St. Lab. Nat. Hist. Surv. No. 17, 1928.

Fritsch, F. E., "Bibliography of English and American Papers on Hydrobiology." *Rev. d'Hydrol.*, 1920, Vol. 1.

Furneaux, W., *Life in Ponds and Streams.* Longmans, Green, 1906.

Galloway, T. W., *The Common Fresh-water Oligochaeta of the United States.* Trans. Amer. Misc. Soc. No. 30, 1911.

Geiser, S. W., *The Distribution of Pectinatella Magnifica Leidy in the United States.* Field and Lab. Vol. 2, 1934.

Morgan, Ann, *Fieldbook of Ponds and Streams.* Putnam, 1930.

Muttkowski, R. A., *The Fauna of Lake Mendota.* Trans. Wisc. Acad. Sci., Arts, Let., No. 19, 1918.

——, *The Respiration of Aquatic Insects.* Bull. Brooklyn Ent. Soc. 15, 1920.

Needham, J. G., *Burrowing Mayflies of Our Lakes and Streams.* Bull. U. S. Bur. Fisheries 36, 1920.

Needham, J. G., et al., *A Biological Survey of Lake George, N. Y.* State of N. Y. Conserv. Comm., 1922, pp. 3–78.

Needham, J. G., and Lloyd, J. T., *The Life of Inland Waters.* Comstock Pub. Co., 1930.

Needham, J. G., and Needham, P. R., *A Guide to Fresh-water Biology.* Amer. Viewpoint Soc., 1927.

Old, M. C., *Environmental Selection of the Fresh-water Sponges of Michigan.* Trans. Amer. Mic. Soc. No. 51, 1932.

——, *Taxonomy and Distribution of the Fresh-water Sponges of Michigan.* Mich. Acad. Sci., Arts, Let., No. 15, 1932.

——, *A Contribution to the Biology of Fresh-water Sponges.* Mich. Acad. Sci., Arts, Let., No. 17, 1933.

Pearse, A. S., *Animal Ecology.* McGraw-Hill, 1926.

Potts, E., *Fresh-water Sponges; a Monograph.* Proc. Acad. Nat. Sci., Philadelphia, 1887.

Reed, C. A., *Goldfish, Aquaria, and Ferneries.* Doubleday Page, 1909.

Scott, F. M., *Introduction to the Limnology of Searsville Lake.* Stanford Univ. Pub., Biol. Sci. 5, 1927, pp. 3–83.

Scott, W., *Report on the Lakes of the Tippecanoe Basin (Indiana).* Indiana Dept. Conserv., State of Ind., Pub. 107, 1916.

——, *Investigations of Indiana Lakes. The Lakes of Northeastern Indiana.* Dept. Conserv., State of Ind., Pub. 107, 1931.

Shelford, V. E., *Animal Communities in Temperate America.* Univ. of Chicago Press, 1913.

——, *Laboratory and Field Ecology.* Williams and Wilkins, 1929.

Smith, F., *Distribution of the Fresh-water Sponges of North America.* Ill. State Lab. Nat. Hist. Surv. No. 14, 1921.

Smith, G. M., *The Fresh-Water Algae of the United States.* McGraw-Hill, 1933.

Stephenson, J., *The Oligochaeta.* Oxford Univ. Press, 1930.

Stromsten, F. A., *Lake Okoboji as a Type of Aquatic Environment.* Univ. Iowa Studies, Studies in Nat. Hist., No. 12, 1927.

Walton, L. B., "Naididae of Cedar Point, Ohio," *Amer. Nat.*, Vol. 40, 1906.

Ward, H. B., and Whipple, G. C., *Fresh-water Biology.* John Wiley and Sons, 1918.

Welch, Paul, *Limnology.* McGraw-Hill, 1935.

Welch, P. S., *Studies of the Enchytraeidae of North America.* Bull. Ill. State Lab. Nat. Hist. No. 10, 1914.

——, *The Genera of the Enchytraeidae (Oligochaeta).* Trans. Amer. Mic. Soc. No. 39, 1920.

Young, R. T., *The Life of Devils Lake, North Dakota.* Publ. N. D. Biol. Sta., 1924.

CHAPTER IX

THE LIFE ON AN OCEAN BEACH

While a great number of people never have the opportunity to study at first hand the animals that are to be found on an ocean beach, these animals are of such a peculiar and often spectacular nature that they command considerable interest among the people who seldom if ever see them. Most nature books display pictures of the queer-looking and picturesque creatures that live between the tides or in the shallow waters along the shore.

A great number of animal phyla are represented in even a limited section of the seashore. Among these are worms, jellyfishes, sponges of many kinds, corals, ctenophores, colonial hydroids, sea feathers, sea anemones, bryozoans, starfishes, brittle stars, sand dollars, sea urchins, sea lilies (crinoids), sea cucumbers, clams, snails, conchs, nautilus, squids, octopus, hermit crabs, chitons, lobsters, crabs, shrimps, sea spiders, horseshoe crabs, and numerous small crustaceans that are closely related to fresh-water forms.

Occasionally during heavy storms, fishes of many kinds including the unique sea horses and sharks, and even whales, are sometimes tossed up onto the beach by the waves. Sea lions are occasionally seen on the rocky beaches in a few sections; and during the mating seasons the giant sea turtles come to the sandy beaches to lay their eggs. In addition to the animals listed here there are eggs and egg masses of many sea-dwelling animals; and sea weeds of many kinds as well.

Numerous birds patrol the beaches; and gulls, terns, herons, sandpipers, plover, fish hawks, pelicans (in southern waters), ducks, and a host of other waterfowl may be seen, sometimes in abundance.

It should be mentioned that many of the animals listed here are on the beach due to accidental transportation. Many of them live in the shallow waters off the shore; and since most of them are sessile, floaters, or poor swimmers, they are either left stranded by the receding tide or they are torn from their attachments by high waves which deposit them on the beach. The jellyfishes represent a

group that are, in the main, floaters, although some of them have weak powers of locomotion. These become ready victims of wave action.

It must not be supposed that all of the animals mentioned above will be found on any one beach or in any one section of the coast. Some of them are northern, while others are more southern in their distribution. Furthermore, the kind of beach will determine, to a large extent, the life that is to be observed on it. Sandy beaches, pebbly beaches, muddy beaches, and stony beaches will all present different faunas, although some of the animals will be found on all of them since waves do not discriminate among beaches upon which to cast helpless victims. The presence of inlets, tidewater pools, and estuaries along the coast provide additional haunts in which many shallow water animals can be studied alive.

The drift line, in which are to be found numerous sea-dwellers, also attracts birds, spiders, tiger beetles, carrion beetles, ants, flies, and other animals which do not form a counterpart of the oceanic fauna. Some of the animals on the beach are permanent residents there, burrowing into the sand when the tide comes in and awaiting its recession, or they retreat before the rising water. Many of the beach-dwellers live in burrows beyond the high-tide level and come out to forage only at night. The best time to study the beaches is from twilight to dark and early in the morning just before the rise of the sun. At these times many of the swimming forms which avoid the shallows in the daytime come close to the shore where they can be observed. The writer, while studying the Florida west coast and the coast of the Adriatic Sea in Italy and in Jugoslavia, used a powerful flashlight at night and was well rewarded for his efforts. Many additional species can be collected and observed at night under favorable conditions, especially the luminous ctenophores, jellyfishes, crabs, worms, and protozoans. Any student who has the opportunity to study the ocean beach should not miss the thrills of seeing the light-producing organisms at night.

It is evident that the list of animals mentioned here is too large for discussion in a work of this kind. Furthermore there are thousands of others including rotifers, protozoans, minute crustaceans, and a host of species of shelled mollusks which have no place here.

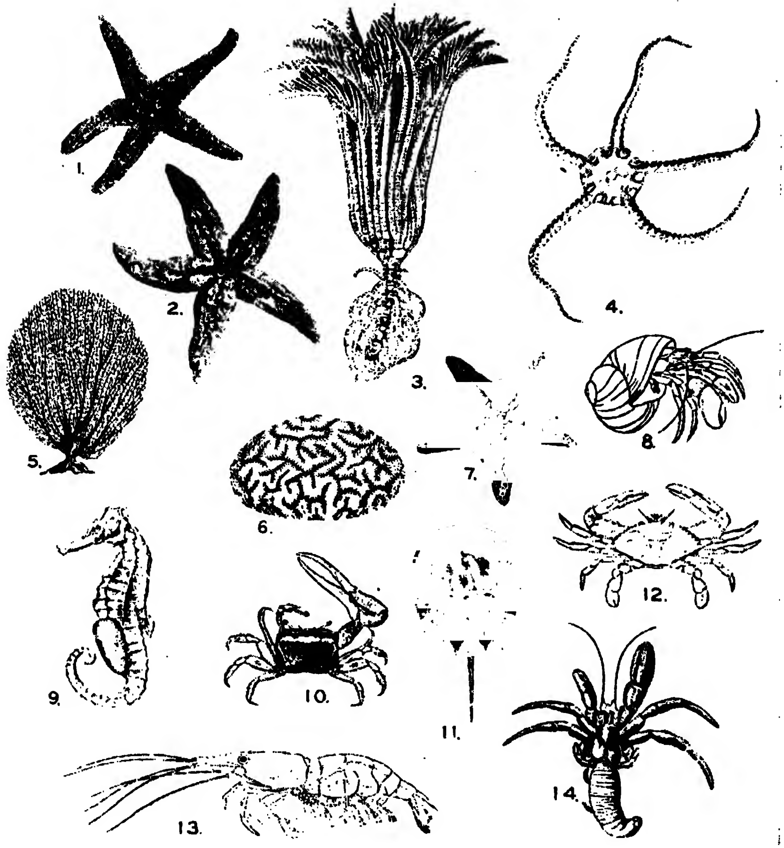


PLATE II. Common animals of the seashore. 1. Starfish (*Asterias*) aboral view; 2. Oral view showing tube feet, from Gen. Biol. Supply Co.; 3. Crinoid (*Pentacrinus maclearanus*), from *Cambridge Natural History* after Hegner; 4. Aboral view of a brittlestar (*Ophioglyphus bullata*), after Thompson from Hegner; 5. Sea fan (*Gorgonia*) (*Coelenterata-Anthozoa*); 6. Brain coral, from Gen. Biol. Supply Co.; 7. Starfish (*Asterina*), from Gen. Biol. Supply Co.; 8. Hermit crab (*Pagurus*) in a snail shell, after Hegner; 9. Sea horse fish (*Hippocampus*), after Hegner; 10. Fiddler crab (*Uca crenulata*); 11. King crab (*Limulus polyphemus*) (*Arachnida*); 12. Edible crab (*Callinectes*), after Hegner; 13. Prawn (*Crustacea-Palaemonidae*), from Hegner; 14. Hermit crab out of a shell, after Hegner.

We shall briefly discuss the most common and striking forms only, although these are not necessarily the most interesting. Many books have been written about the inhabitants of the beaches and about oceanic animals in general. The most available general volumes are listed at the end of this discussion.

The echinoderms. The echinoderms are characterized by tough or hard outer coverings which bear spines (excepting the Holothurians) and other structures. All are radially symmetrical in the adult stage, and most of them are composed of five radiating parts or antimeres. There are no terrestrial or fresh-water echinoderms, which is characteristic only of this phylum.

There are many species of starfishes, but all of them are built on the same general plan usually with five (or multiples of five) arms or antimeres radiating from a central disc producing the well-known star shape. There are a few exceptions to the pentamerous arrangement, notably the 6-rayed starfish of the west coast. The covering is a thick, tough integument from which protrude blunt, calcareous spines. At the bases of the spines are pincer-like structures known as pedicellariae which seem to function in keeping the body surface clean and especially the membranous protrusions called dermal branchiae which are respiratory structures. In the central disc there is a stony, hardened, roundish structure called the madreporite which is the opening of the water vascular system.

The anal opening is also located on the aboral body disc, but it is usually invisible. At the tip of each antimere, arm, or ray is a reddish eye spot.

On the underside or oral side may be seen the centrally located mouth surrounded by a fleshy peristome. Extending from the peristome in each arm is a groove known as the ambulacral groove. It is lined with movable ambulacral spines. From the groove extend the long, cylindrical tube feet by means of which the starfish moves about. The action of the tube feet is regulated by internal structures called ampullae. With the tube feet the starfish can cling tenaciously to rocks and other objects, and with them it adheres by means of suction to the shell of an oyster which is one of its foods. By exerting a steady pressure the shell muscles of the oyster weaken and the valves gradually open. The starfish then devours the oyster by everting its fleshy stomach over the body of its prey. It is interesting to note that a starfish can automatically shed an arm (autotomy), and it can regenerate any part that may

be lost through accident. Starfishes inhabit the shallow water in the tidal zone. They are often of brilliant hue. Some species are shown in Plate II (Figs. 1, 2, 7).

The brittle stars or serpent stars resemble starfishes in general form, but their arms are long, slender, and serpentine in shape and movement. They lack the ambulacral groove and they have no pedicellariae or anus. The usual number of arms is five, although some species have six. The oral side is the underside and the mouth is star-shaped.

The sea urchins are almost hemispherical, most of them having convex aboral or upper surfaces. The skeleton is composed of elevated, greatly convex, calcareous plates, fused together. It is compact, but its pentamerous structure is quite visible when the spines are removed. The spines which are movable cover the entire upper surface of the body and give it the appearance of a hedgehog from which the echinoderms derived their name. In some species the spines are very long, while in others they are comparatively short. Pedicellariae are present, but they usually have three jaws instead of two, which is the number in starfishes. The oral surface is downward, and it is flatter than the aboral or dorsal side. Movement is effected by the spines on the periphery of the ventral or oral side. The mouth is located in the center of the oral surface.

Sand dollars are the flattened, brittle, disc-like animals frequently found on the beach. The skeleton is found much more frequently than the whole animal. The sand dollars are closely related to the sea urchins, but their oral surface is very flat and the dorso-ventral depth is small. For this reason they are given the common name sand dollar to distinguish them from the sea urchins. The aboral or dorsal surface is usually arched or ridged. The skeleton is composed of five antimeres which are attached to a central body disc. The body is covered with calcareous plates and short spines which are easily rubbed off. Sand dollars (native) range in size from finger-nail size to five or six inches in diameter.

The sea cucumber is a fleshy, elongated, more or less cylindrical echinoderm which lives at varying depths and which is often found washed up on the beach or in the shallow water off shore. The skin is usually warty and flexible; and it lacks the calcareous spines which characterize starfishes and sea urchins.

The sea cucumber does not have the oral side directed down-

ward. It rests, as a rule, on one side at the bottom with the mouth at one end of the cylindrical body. The mouth is surrounded by ten or more long, branched tentacles which are in constant motion when the body is extended. When disturbed, the sea cucumber contracts so quickly that water is forcibly ejected.

The mollusks. The squid, *Loligo pealei* (Plate III, Fig. 8), is an elongate, somewhat cylindrical, but partly flattened cephalopod which inhabits the waters of the Atlantic coast. There are eight fleshy, sessile, tentacular arms and two elongated tentacles attached to the head. Both the arms and tentacles are supplied with rows of suckers, the former with two rows and the latter with four rows. A pair of prominent eyes are located on the sides of the head. The upper surface is covered with a mantle, and fins are present. The internal shell is long, chitinous, and pen-shaped. The siphon is visible underneath the head. Squids are excellent swimmers and pursue their victims with amazing speed. When pursued themselves, they discharge inky material into the water. This clouds the water and makes it possible for them to escape their enemies in darkness. There are many rather common squids throughout the world, and all of them are built on the same general plan. One species is said to attain a length of fifty-five feet and is the largest of all invertebrates.

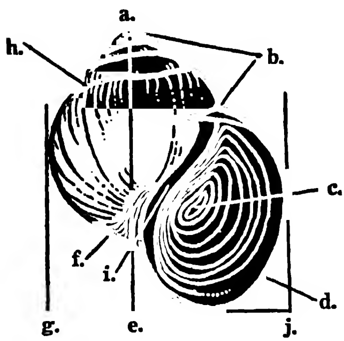


Fig. 48. The features and measurement of a snail shell. a. Apex; b. Spire; c. Operculum; d. Lip; f. Umbilicus; h. Suture; i. Columella. a.–e. height; g.–j. diameter. After Melassonos.

The octopus or devil fish is one of nature's grotesque monsters (Plate III, Fig. 6). It is feared in many sections where the species attain a large size. The smaller forms are often found attached to rocks in tidal water. There are eight arms or tentacles, and these have several rows of suckers on the undersides. With these arms the octopus encircles its victim which is held by the suckers. Like the squid, the octopus discharges black fluid from its ink bag in order to confuse its enemies when it is pursued or attacked. Like the squid it can change its color and is edible. They both belong to the *Cephalopoda* (head-feet).

The shelled mollusks comprise those with one valve (univalve)

and those with two valves (bivalve) shells. The common oysters, clams, scallops, fan shells, angel wings, edible mussels, bearded mussels, and scores of others are bivalvular. The shells may be heart-shaped, fan-shaped, circular, or oval. Some of them are almost triangular. The shells may be rough, smooth, or corrugated. Some of them are almost transparent and thin, while others are thick and opaque. A number of them are brilliantly colored, although in many species the conspicuous shell markings do not appear in living animals.

The valves are hinged and often teeth are present. In most of them the valves are opened and closed by adductor muscles which are attached to the inner surfaces of the valves. A mantle is present and this secretes the shell. Lines of growth are usually visible on the shell. The structure of the shell is described in connection with fresh-water mussels. Locomotion is effected in several ways. Some of the bivalves swim by opening and closing the shell, while others (Pelecypoda) have a hatchet-shaped foot by means of which they propel themselves. Some bivalves burrow while others remain on the bottom or swim about in search of food. In the more sedentary forms two siphons are usually present.

FIG. 49. Egg mass of a giant sea snail or whelk.

It would not be possible to describe any number of individual species here, but some of them are pictured in Plate III. The bivalves range in size from dainty finger-nail clams to gigantic forms (over four feet) in the South Seas. These large mollusks are a serious menace to swimmers. They belong to the Class *Pelecypoda* (hatchet-feet).

The univalves include the well-known conchs in which the "noise of the sea" can be heard when they are held to the ear. The noise is really the circulation of blood in the listener. Snails, tooth shells, limpets, ladder shells, the measled cowry, cameos, helmet

shells, nautilus, and others have univalvular shells which may be chambered. Some of them are pictured in Plate III. Most of them are gastropods and move about on the underside of the body (stomach-footed).

The chitons are bilaterally symmetrical mollusks with an anterior end bearing the mouth and a posterior end in which the anus is located. The shape of the body is oval and the shell is composed of eight transverse plates. Most species of chitons have a ridge along the median line (Plate III, Fig. 13). Chitons belong to the Class *Amphineura* (double-nerve).

The coelenterates. Jellyfishes are commonly found on beaches almost everywhere. Being weak swimmers, they are transported mainly by currents, and they become easy victims of the waves and tides which toss them onto the beaches. They are almost transparent, jelly-like animals with a circular outline. The dorsal surface is convex (exumbrella), and the underside or oral surface is concave (subumbrella). Most of the jellyfishes belong to the Class *Scyphozoa* (cup-animals).

The jelly-like material is called mesoglea, a non-cellular substance between the two cell layers of which the bodies are composed. Within the body may be seen radiating lines which are canals. The canal systems are variable in the host of species that exist. A hollow interior in which the stomach pouch or pouches are located may also be observed. The convoluted structures along the canals or in the stomach pouch are the gonads or reproductive organs. These proliferate the germ cells. Usually the sexes are separate.

Around the periphery of the jellyfish and suspended downward are numerous tentacles of varying length according to species. These tentacles are supplied with specialized cells which manufacture nematocysts or stinging hairs which are irritating and frequently poisonous. When a jellyfish is disturbed, thousands of these nematocysts are discharged, and they penetrate the bodies of enemies. Jellyfishes should never be handled when they are alive, and the observer should exercise the precaution of making sure that the animals are dead before picking them up. On the oral surface is the four-sided mouth or manubrium surrounded by oral arms which hang downward. In some species a membranous covering or fold is present on the subumbrella or around the periphery. This is called the velum. The jellyfish does not swim

by using the tentacles, as one would suppose, but largely by contracting the bell-shaped body and forcing water from beneath the velum or from the body cavity. The life histories of jellyfishes are often very complex and the early stages are generally very different from the adult stages. Jellyfishes are simply constructed; and yet they have organs of equilibrium on the periphery. The balancing structures are variable in number and complexity. On the small jellyfish, *Gonionemus*, there are four of these structures known as statocysts. In the common scyphozoan jellyfish (*Aurelia*) of the Atlantic coast there are eight more highly developed organs called tentaculocysts. There are many species of jellyfishes, and they range from microscopic forms to huge animals several feet in diameter. These larger ones may be very dangerous. The common species of jellyfishes on the Atlantic coast are *Aurelia* (4 inches), *Gonionemus* (1 inch), *Eutima* (2½ inches), *Zygodactyla* (5 inches), and *Aequorea* (3–5 inches). The jellyfishes are sometimes brilliantly colored. Many of them can change color, and numerous species are luminescent. The student can ascertain the structural features in detail by referring to *College Zoölogy* by Hegner (The Macmillan Company).

Related to the jellyfishes are the corals. These coelenterates construct stony skeletons to support their soft bodies. Some of them are unique in appearance, assuming varied shapes as illustrated by the staghorn coral, star coral, fan coral, and brain coral. Corals are most abundant in warm seas, and a number of them are used in making jewelry. It may be mentioned that individual corals are flower-like animals with tentacles. They live in tree-like colonies as a rule, and a colony may contain hundreds of individuals. Their skeletons compose the well-known coral reefs. Adult corals are sessile. A number of corals are shown in Plate II.

The sea anemones are flower-like, solitary, sessile or sedentary coelenterates, as a rule. They are erect, cylindrical animals with numerous tentacles around the upper end in the center of which is the mouth. Many of them, too, are brilliantly colored, the purple ones being very conspicuous. The base is a broad, adhesive foot which clings to objects although the animals can move about. In addition to stinging nematocysts, the sea anemones have long, hair-like structures called acontia which they can forcibly extend through pores in the body wall. The acontia are well supplied with

nematocysts. The common, brown *Metridium* is the genus most commonly found on the northern coast, while *Sargartia* is the most common species southward. One worm-like, burrowing species, *Eloactis producta*, extends along the Atlantic coast from Cape Cod almost to Florida. Living sea anemones should also be handled with care. The corals and sea anemones belong to the class *Anthozoa* (flower-animals).

Not infrequently there are plant-like structures with stems and branches on the beach, and they can easily be mistaken for small plants. When examined with a magnifier, the student may be even more convinced that they really are plants. However, a close examination will show that they are colonies of small, sometimes very minute, coelenterates called hydrozoans.

The stem is the mother animal, and small flower-like members of the colony grow as buds on the main stem. They are called hydranths. Each bud or branch represents an animal; each has tentacles surrounding a mouth; and each captures food with its tentacles, which have nematocyst cells. The tentacles also transfer food to the mouth, which is surrounded by a raised portion called the hypostome. The food is digested by the cells lining the gastral cavity or coelenteron, after which the phylum is named (*Coelenterata*—" hollow-intestine "). On each colony of hydrozoans there are buds or branches which are different in appearance from the hydranths and which lack the tentacles. These are the gonangia or reproductive animals, and they take care of the propagation of the animal colony. In the gonangia small medusa buds are produced. These medusae resemble tiny jellyfishes, which they really are. The medusae proliferate the germ cells which unite and start a new colony. Two interesting factors are observable in this method of reproduction. In the first place, the colony starts from medusae and then develops into hydroids or polyps. Secondly, the colony starts by sexual methods, and the animals grow as branches or buds on the main stem or mother animal by asexual methods, thus effecting metagenesis or the alternation of generations. The presence of more than two kinds of animals in a colony is an illustration of polymorphism. This organization is not characteristic of all hydrozoans, however, but it is found with some slight modifications in *Sertularia, Campanularia, Bougainvillea,* and especially in *Obelia*. The colonies of these animals are several inches in length and grow in the shallow waters attached to rocks and other objects.

The details of structure can be found in almost any zoölogy text. Other genera are: *Stomotoca, Eudendrium, Rathkea, Pennaria, Hybocodon, Thuiaria, Antennularia,* and *Tubularia.* These and also hydras and the jellyfish *Gonionemus* belong to the Class *Hydrozoa* (serpent-animals). The serpent-like tentacles on them are responsible for the name.

The arthropods. The arthropods have many representatives in the beach fauna. This phylum contains more species than all other animal groups together. The main and distinguishing characters of the arthropods are discussed elsewhere. It might not be amiss to mention here, however, that crustaceans, spiders and their relatives, myriapods, and insects belong to this group. Of these the crustacea are most numerous in the ocean fauna, although many insects are attracted to the decaying bodies of marine animals on the beach.

The largest and most conspicuous crustaceans seen on beaches are the lobsters. Very few of them are ever found on the beach however. The characters of the lobster are largely those of the crayfish (Fig. 24), and its chief differences are those of size and habits. The lobster is rather northern, and it is taken in great abundance for food. On the Florida coast and the Gulf coasts, however, there occurs the spiny lobster or Florida crayfish which has a great commercial value. It differs from the true lobster by the absence of pincers, its spiny carapace, and smaller size.

Crabs are numerous all along the coast; and many of them are valued highly as food. In the crabs the cephalothorax is short and broad; the antennae are short; there are few abdominal appendages, and these are used primarily for reproductive purposes; the eyes are stalked; and the abdomen is almost invisible from above because it is bent under the carapace.

Some of the smaller crabs include the oyster crab (*Pinnotheres ostreum*), the female of which inhabits the mantle cavity of the oyster. The male is free-living. The mussel crab (*P. maculatus*) lives in the mantle cavity of the mussel. This species is from eight to ten mm. long.

The ghost crab (*Ocypode albicans*) has a square carapace with distinct, raised margins at the sides. The eyes are club-shaped, and the legs have tufts of bristles on their edges. This species is about four cm. long and is found in burrows where it rests during the day. At night the crabs emerge by the thousands and patrol

the beaches. Their burrows are usually near the high-tide level, but occasionally further away from the water.

The green crab (*Carcinides maenas*) is about four cm. long with the carapace broader than long. There are five acute teeth on each side of the carapace. It is usually found under masses of seaweed or under rocks in the tidal zone.

The lady crab (*Ovalipes ocellatus*), so-called because of its bright color, is an inhabitant of sandy bottoms where it buries itself, leaving only its stalked eyes protruding above the sand. The yellow color is marked with spots of reddish purple. The species is 5 cm. long and 6 cm. wide.

The mud crab (*Panopeus sayi*) measures 1.6 cm. in length and 2.5 cm. in width. It is one of several species found under stones on the beach below the high-tide mark.

The toad crab, measuring eight cm. in length and 6.5 cm. in width; the rock crab (*Cancer irroratus*), which is about seven cm. in length and ten cm. in width; and the northern crab or Jonah crab (*C. borealis*), which is about the same size, are found in the shallow offshore waters among débris.

The edible blue crab (*Callinectes sapidus*—Plate II, Fig. 12) is the largest with a length of seven cm. and a width of 13 cm. It is the species commonly served in restaurants. The color is bluish, and there are eight teeth on the margin between the eyes and the lateral spines. The last pair of legs have the terminal joints flattened into oar-like paddles for swimming.

Another interesting tiny species, measuring 2.5 cm., which is found in burrows close to the low-water mark and occasionally running with the wash of sand, is the "sand bug" crab. It is oval in shape and strongly convex above. The second pair of antennae are curved and plume-like. The eyes are borne on slender stalks, and none of the legs are chelate. The color is whitish with tints of lavender above and yellowish on the underside.

The hermit crabs are those which inhabit the empty shells of gastropod mollusks. These shell homes are carried about with them as a protection for their soft abdomens. They are very common on the beaches where they may be seen dwelling in shells with their strong pincers extended. The one claw is considerably longer than the other, and they are often referred to as the long-armed crabs. One species is called the hairy or warty hermit

crab (*Pagurus pollicaris*). It is considerably larger than *Pagurus longicarpus*, which is more common.

The fiddler crabs are the most interesting of all. They burrow in the sand at a considerable distance from the water. The entrance of the burrow usually has an arched mound of sand, and in the entrance the crab stations itself. In the females the pincers are of equal size, but in the males the right one is greatly developed. The movement of the pincers or chelipeds is that of a fiddler sawing with a bow. The largest species is 2.5 cm. long and 3.5 cm. wide (Plate II, Fig. 10).

Attached to rocks and the piling supporting wharves are seen the barnacles, comprising a number of common species. The shells of the barnacles are very hard in comparison with other crustaceans. The six pairs of hairy legs are curled; hence the name *Cirripedia*, which means curl-footed. The familiar goose barnacles have the shell mounted on a long stalk. The ivory barnacle (*Balanus eburneus*) is sessile and has a low, conical shell. It and other related species in the family *Balanidae* are commonly found attached to the shells of mollusks such as oysters.

Aside from the almost microscopic crustaceans such as ostracods and cladocerans, there are water sowbugs (*Isopoda*) not vastly different from the fresh-water forms. A great number of scuds or benders (*Amphipoda*) are also to be found in the water at its edge.

The arachnida. The horseshoe crab, *Limulus* (Plate II, Fig. 11), is a large crab-like animal which really belongs in the spider group (Arachnida). Its body is composed of a horseshoe-shaped cephalothorax, a roughly triangular abdomen, and a long, spine-like tail which is as long as the rest of the body. The dome-shaped anterior of the cephalothorax bears a pair of compound eyes and a pair of simple eyes. On the lateral margins of the abdomen there are rows of movable spines.

There are six pairs of legs. The first pair are small and bear weak claws. There is also a tuberculate organ on the first pair of legs, and this is supposed to function as an olfactory organ. On the terminal segments of the sixth pair of legs there is a leaf-like expansion known as the flabellum which is for the purpose of aiding the animal as it pushes itself through the sand. The pincers on the second legs of the male are somewhat enlarged for clinging to the female. The six pairs of plates which comprise the operculum and gills are arranged so as to form a respiratory book. The

queer-looking, eight-legged, crawling, spider-like animals found among débris or clinging to hydrozoans are sea spiders which are of uncertain position, taxonomically. Many of them are grotesque in form. All native sea spiders are small, measuring not more than two cm. in length and with a spread of not more than 140 cm. Giant forms inhabit the great depths of the ocean.

The insects are all terrestrial or fresh-water inhabitants. Only one, *Halobates*, a strider, is found on the ocean where it skims the surface of the water.

The student who studies the ocean beach should collect everything available and then refer to technical works or special books for complete data.

The sponges. The sponges, while many-celled, are very lowly animals with little justification for their being placed among higher animals. They are all sessile and sedentary in the adult stage, and the greater number of them are immobile when young. As a result of their sessile habits, the sponges assume the general forms of plants. In the sponges, the two cell layers are separated by a thin layer of jelly. The jelly is conspicuous in only a few species of sponges.

The body of a simple sponge consists of a central cavity surrounded by the inner cell layer and with an opening at the free end called the osculum. Through the osculum waste products are discharged with the discharge of water. The body is supported by a skeleton constructed by the outer layer of cells, and it is perforated with myriads of small pore-like openings through which water enters the body. In complex sponges, the pores open into canals which conduct the water carrying food into the gastral or body cavity where digestion takes place. The cells of the inner layer take care of nutrition.

The skeleton in some sponges is composed of calcareous, needle-like structures called spicules. These are variable in shape. In other sponges such as the household varieties the skeleton is composed of soft material with the texture of silk. This is called spongin.

Sponges are most abundant in tropical and subtropical seas, and they are cultivated in sponge gardens on the floor of the ocean for commercial purposes. Sponges reproduce chiefly by budding, although gemmulation and modified sexual methods are employed in some species, particularly in fresh-water forms. In bud-

ding, the new sponge simply grows as a branch on the parent animal.

Sponges are classified on the bases of skeletal structure and on the complexity of the canal systems. In the latter classification there are ascon (a simple connection between the outside and the gastral cavity); sycon (a more complex system with incurrent canals, prosopyles, apopyles, and radial canals); and rhagon (a very complex canal system) types. Technically and taxonomically sponges are grouped according to their skeletons. The principal classes are *Calcarea, Hexactinellida,* and *Demospongiae* (sponge of the people).

On the beach, sponges are abundant. The simple sponges which are usually small (one-half to one and one-half inches) are found attached, sometimes in colonies, to rocks and shells. *Leucosolenia* (ascon), which is common in shallow water from New Jersey northward, and *Grantia* (sycon), which has about the same range, are common. They have skeletons composed of spicules of lime.

The finger sponges, *Chalina oculata* and *C. arbuscula,* are rather small sponges which have a dendritic or tree-like shape. There may be numerous branches, and the height is about one and one-half inches. The bread crumb sponge (*Halicondria panicea*), which is shaped like an irregular mass of bread, grows in a mass several inches in diameter. Living specimens are usually yellow or orange in color.

Many of the tree sponges are bright red in color; and *Esperiopsis obliqua,* which stands about eight inches high, is fairly common on the entire Atlantic coast. Larger species are found in Florida waters.

Euspongia is a genus with varied individuals including the glove sponges. These are sometimes called basket sponges. Their shape is a section of an inverted cone. The sheep's wool sponge grows like a mass of wool, and the horse sponge (*Hippospongia*) is also like a piece of conical, rough pottery which is wide at the top. All of these are soft sponges and have some commercial value.

The student is urged to use special works for identifying the sponges since there are so many species found on the Atlantic and Gulf coasts.

The worms. There are myriads of small worms inhabiting the shallow waters along the shore where they are usually associated with algae or débris. There are also many that burrow into the

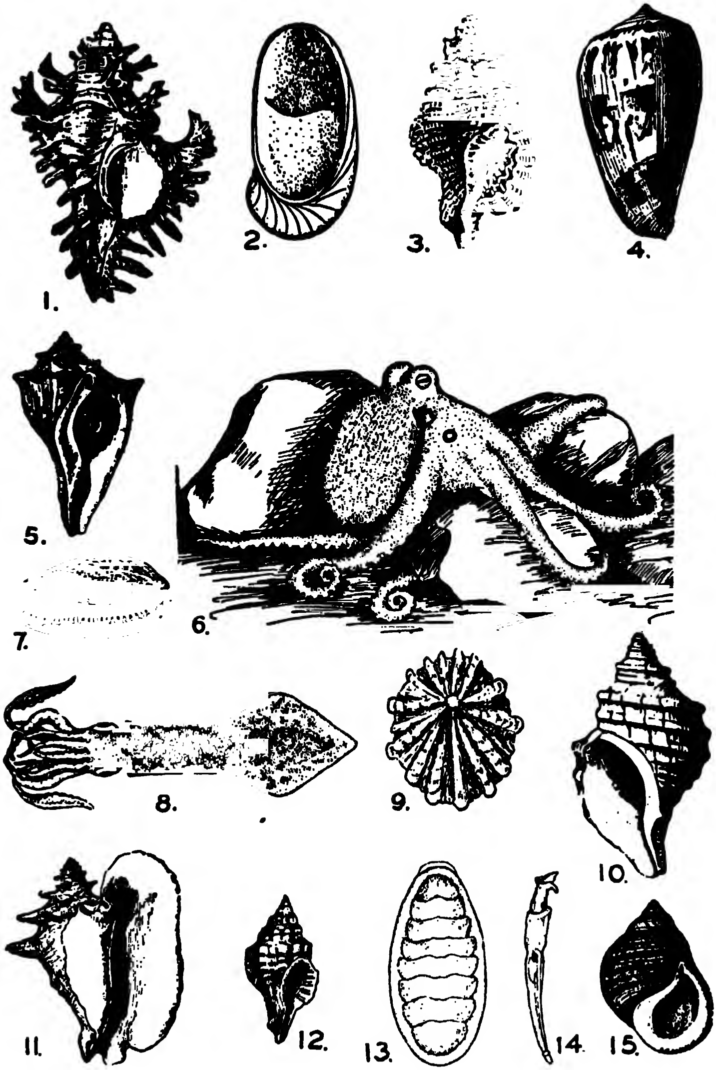


PLATE III. Some animals occasionally found on the ocean beach. 1. Murex, from Hegner after Tryon; 2. Crepidula, from Hegner after Tryon; 3. Charonia, from Hegner after Tryon; 4. Conus; 5. Busycon, from Hegner after Tryon; 6. Octopus, from Hegner after Johnson and Snook; 7. Cypraea; 8. Squid, from Gen. Biol. Supply Co.; 9. Acmea, from Hegner after Tryon; 10. Neptunea; 11. Strombus, from Hegner after Tryon; 12. Urosalpinx, from Hegner after Tryon; 13. Chiton; 14. Dentalium; 15. Littorina, from Hegner after Tryon.

sand in the intertidal zone. However, many of these worms are so obscure and so difficult to identify that it requires a broad knowledge of helminthology to classify them. There are, however, a few larger forms of interest. It is always a good idea to collect intensively and then take the material to the laboratory where binoculars and references are available. Worms can be found in tubes which are often attached to shells and rocks, and other forms can be collected by carefully examining algae and masses of weeds. Many kinds of worms lie buried in the sand with only the head protruding. Free-swimming forms are best collected in fine mesh nets. All can be preserved in 80 per cent alcohol or 15 per cent formalin solution.

The sandworm, or marine worm, *Nereis*, is the most conspicuous form. It is a polychaete (many bristles) annelid or segmented worm that is common on beaches. *Nereis* has a well-developed head and a total of sometimes 200 segments. Fleshy protrusions called parapodia extend from the sides. These increase the respiratory surface since the animal breathes through the body surface. *Nereis* lies buried in the sand when the tide is in. Most zoölogy classes study this worm which may reach 30 cm. in length. Males are steel blue with green at the bases of the parapodia, while the females are greenish and tinted with red and orange.

The scaleworms are distinguishable by the series of plates or elytra along the lateral margins. They range in size from three cm. to 15 cm.

The lugworm is an elongated, cylindrical form with a swollen anterior region which is blunt at the end. The parapodia are rudimentary, and those in the middle region bear gills. The color is dark, brownish green. It lives in deep burrows near the low-tide level and may reach a length of 20 cm.

The above worms are related to earthworms, and they represent but a few of the numerous species to be found.

The sea horse. While there are numerous fishes to be found on the beach, they are as a rule infested with maggots and other insects and therefore unpleasant to handle. There is one inhabitant of the shallow seas where marine plants grow that is vastly different from other fishes. In fact it is so unique that it could easily be mistaken for something other than a fish. The sea horse (*Hippocampus*) is a true bony fish (Plate II, Fig. 9) which bears a superficial resemblance to a horse-head. It is a small fish, being only

several inches long. It lives among the water plants where it suspends itself by holding on to the plant stems with its tail. The sea horse holds its head erect and swims by moving its body back and forth with a bobbing or hobby-horse movement. The breeding habits of this fish are unique. The eggs are carried in a pouch on the underside of the body of the male where they remain until hatched. The young stay in the pouch until they are able to take care of themselves.

A salt-water aquarium. Many of the animals characteristic of the beach association can be kept alive in the home or in the laboratory in salt-water aquaria. Starfishes; snails and other gastropods; bivalves such as clams; chitons; sea anemones; sea urchins; sea squirts; jellyfishes; crabs and smaller crustaceans; the horseshoe crab; marine worms; and many others can be kept for a considerable time. Many biological supply houses are prepared to supply living animals to those who cannot collect them. Ocean water is supplied with the specimens which can be placed in an ordinary aquarium tank. The water should be aerated, and simple and inexpensive devices for keeping a constant flow of air through the water are now obtainable.

The salt-water aquarium provides an opportunity for observing the movements of animals that are seldom seen in the living state. Some of the marine animals will not endure the artificiality of a small tank for very long, but they can be kept alive long enough to observe their habits. Other sea-dwelling animals can be kept from one year to another under ordinary conditions.

BIBLIOGRAPHY

Animals on the Seashore

Arnold, A. F., *The Sea Beach at Ebb Tide.* Century, 1901.
Calman, W. J., *The Crustacea of New Jersey.* Rep. N. J. State Mus., 1911.
Clark, A. H., *Animals of Land and Sea.* Van Nostrand, 1927.
Coe, W. R., *The Echinoderms of Connecticut.* Conn. Geol. and Nat. Hist. Surv., 1912.
Crowder, William, *Dwellers of the Sea and Shore.* Macmillan, 1923.
——, *A Naturalist at the Seashore.* Century, 1928.
——, *Between the Tides.* Dodd Mead, 1930.
Flattely, F. W., *The Biology of the Seashore.* Sedgwick and Jackson, London, 1922.

George, W. C., and Wilson, H. V., *Sponges of Beaufort and Vicinity.* Bull. U. S. Bur. Fisheries, Vol. 37, 1917 to 1918.

Harmer, S. F., and Shysley, A. E., *Flatworms, Metazoa, etc.* Cambridge Nat. Hist. Series, Vol. 2, Macmillan, 1909.

Heilprin, Angelo, *Animals of Our Seashore.* Lippincott, 1888.

Johnson, M. E., and Snook, H. J., *Seashore Animals of the Pacific Coast.* Macmillan, 1935.

Lankester, Sir Ray, *A Treatise on Zoölogy.* A. and C. Black, 1909.

King, L. A. L., and Russell, E. S., *A Method for the Study of the Animal Ecology of the Shore.* Proc. Roy. Phys. Soc., Edinburgh, Vol. 17, 1909.

Mayer, A. G., *The Medusae of the World,* Vols. 1–3. Carnegie Inst., 1910.

——, *Seashore Life.* N. Y. Zoöl. Soc., 1911.

Miner, Roy W., *Fieldbook of Seashore Life.* Putnam, 1933.

——, "Animals of the Wharf Piles," *Am. Mus. Nat. Hist. Jour.*, Vol. XIII, Feb., 1913.

——, *Outposts of the Sea: Animals of the Tidal Zone.* Am. Mus. Nat. Hist. Guide Leaflet, Ser. 74, 1929.

——, "Diving in Coral Gardens," *Am. Mus. Nat. Hist. Mag.*, Sept.–Oct., 1933.

Moore, H. F., *The Commercial Sponges and Sponge Fisheries.* Bull. U. S. Bur. Fisheries, Vol. 28, 1910.

Nutting, C. C., *American Hydroids, I, II, III.* Bull. U. S. Nat. Mus., 1900, 1904, 1915.

Patch, Edith M., *Holiday Shore.* Macmillan, 1935.

Pratt, H. S., *A Manual of the Common Invertebrates.* A. G. McClurg Co., 1923.

Rathbun, Mary J., *The Spider Crabs of America.* Smithson. Inst. U. S. Nat. Mus. Bull. 129, 1905.

——, *The Grapsoid Crabs of America.* Bull. 97, U. S. Nat. Mus., 1917.

Rodgers, Julia, *The Shell Book.* Doubleday Page, 1909.

Thomson, J. A., *The Haunts of Life.* Harcourt Brace, 1922.

Tryon, G. W., and Pilsbry, H. A., *A Manual of Conchology.* Phil. Acad. Nat. Sci., 1878.

Ward's Natural Science Establishment, *Shell Catalogue.*

(See also the bibliographies for Mollusks, Crustacea, and Fishes.)

CHAPTER X

THE WORMS

Every collector of soil and water life has encountered worms in abundance. The worms constitute a large and generally little-known group of animals, but one which is of vast importance in the so-called balance of nature. There are many species of worms which live parasitically in the bodies of other animals; and nearly every wild creature is infested with some sort of worm parasite, tapeworms and roundworms being the most common.

The name *worm* is generally applied to many animals which are not worms at all. Tomato worms, cabbage worms, chestnut worms, cut worms, army worms, wireworms, meal worms, grub worms, apple worms, and scores of others are really the larvae of insects. The worms may be distinguished from larvae by their having, usually, many more body segments; and they do not, as a rule, have well-developed heads, mouth parts, eyes, or legs.

The free-living species of worms, in which the field naturalist is interested, are to be found in the soil and in aquatic and semi-aquatic situations. These represent several animal phyla, and many of them are extremely difficult to identify. The more common and obvious worms include the earthworm, leeches, fresh-water flatworms, "horsehair" worms, tubifex, and other relatives of the annelids.

The earthworm, fishing worm, or night crawler is the largest and most commonly found free-living, non-parasitic worm; and everyone has some first-hand knowledge about its habits. It is surprising, however, how many persons who have baited hooks with earthworms for many years actually are not acquainted with their external characters and their general habits.

The zealous fisherman knows that earthworms are nocturnal; and when the season opens, he may be seen equipped with a flash-light, crawling over the lawn at night, searching for specimens which have emigrated from their burrows in the ground. Heavy rains sometimes flood the burrows of the earthworms, and they emerge by hundreds and crawl over sidewalks.

Earthworms are entirely vegetarian; and they devour the roots of grasses, strawberries, and other plants. They also feed upon vegetable molds. They are usually found in soil rich in humus, upon which they feed. The worm eats its way through the ground, ingesting the earth and digesting the organic matter. The indigestible sand and other matter passes out of the body with the feces; and the pellets or castings greatly enrich the soil. The amount of soil turned up by earthworms is sufficiently great to be of economic importance. Darwin relates that when he was a boy there was a field so covered with stones that a colt could not run over it without its hoofs striking the stones, and twenty years later the stones were completely covered with the soil upturned by earthworms.

Frequently earthworms come out at night and roll leaves into small cylinders and then draw them into their burrows. Sometimes daylight overtakes them while at work; and being negatively phototropic, they desert their tasks, leaving the rolled leaves protruding from the entrances of their burrows. The burrowing activities of earthworms make the soil porous, and air can penetrate it. This is of agricultural value.

The earthworm has no eyes; but it is able to distinguish among intensities of light, always avoiding bright light; and there is some evidence that it responds to mechanical stimuli, such as vibratory disturbances, thus exhibiting thigmotropic responses. Earth tremors have been known to cause earthworms to leave their burrows, and sometimes merely tapping the ground rapidly will cause them to emerge.

Externally the earthworm is seen to be composed of numerous ring-like body segments, the number usually totaling more than one hundred. The fleshy, anterior segment is the prostomium, which is not a true segment. It overhangs the first body segment projecting from the underside of which is located the inconspicuous, crescent-shaped mouth. On the ventral surfaces of all segments excepting the first three and the last are four pairs of bristle-like setae which hold the body as the animal pushes and pulls itself along. The elongation and contraction of the body is made possible by the setae. The earthworm cannot progress on glass or other surfaces which are not rough and upon which the setae cannot hold. On the dorsal sides of the fourteenth and fifteenth segments, respectively, are located the openings of the oviducts and vasa deferentia or male reproductive ducts. The former are

round, almost invisible pores; and the latter are revealed by swollen lips which enclose the aperture. Extending from segment thirty-one or thirty-two and including segment thirty-seven, is a collar or saddle-shaped enlargement known as the clitellum. This plays a part in the formation of the cocoon, in which the eggs are enclosed, and in the slipping of the cocoon over the head. The cocoons, containing the eggs, are deposited in the ground. While the earthworm is hermaphroditic and therefore has the generative parts of both sexes, it does not fertilize its own eggs; and there is always a congress of two individuals in reproduction.

The anal aperture is a small, oval-shaped opening in the last body segment. There are other small openings on the body, such as the nephridiopores, through which waste products are discharged, and dorsal pores; but these are invisible to the naked eye.

The body of the earthworm is covered with an opalescent cuticle which glistens in bright light. If an earthworm is cut in two near the head, a new head is regenerated; and if bisected further back, a new tail is developed. Experiments have been performed in which the middle was removed; and the anterior and posterior ends were held together until they united, forming a short worm. The earthworms, of which there are several species, belong to the family *Lumbricidae*. One thin, reddish species has a bad odor.

In the trash and ooze at the bottoms of ponds and smaller streams, there is frequently found a relative of the earthworm known as Nais, which is a bristly, writhing, almost transparent, segmented worm about 20 mm. long. Nais belongs to the family *Naididae* which includes several genera which are rather common.

On the bottom may also be seen hundreds of small worms extending from chimney-like tubes or cases. When disturbed, they immediately withdraw into their cases and disappear. These are also related to the earthworm, belonging to the family *Tubificidae* of the Oligochaeta. These worms are known as tubifex, and they may sometimes be red in color. Another curious segmented worm, *Chaetogaster* (family *Naididae*), exhibiting tufts of setae, is frequently found associated with the above species.

The "hairworms" or "hairsnakes" which are frequently seen in watering troughs are parasitic roundworms which have emerged from insects in which they spent a portion of their lives. These long, thin, thread-like worms are supposed by many people to be tiny snakes that have developed from horse hairs. This is, of

course, an erroneous superstition. There are many of these thread-worms, some of them in the soil. They belong to a group known as Gordiacea; and when disturbed, they seem to tie their bodies in knots.

The leeches and fresh-water flatworms have already been discussed under water animals.

The three principal phyla of worms are:

(1) *Platyhelminthes* or flatworms, including the fresh-water flatworm (*Planariidae*), tapeworms (many families), and liver flukes (the several families are unimportant here).

(2) *Nemathelminthes*, the threadworms or roundworms, including the Gordiacea (*Gordiidae*), the parasitic Ascaris (*Ascaridae*), the hookworm (*Strongylidae*), the tropical microscopic worm that causes filariasis or elephantiasis (*Filariidae*), and the pork worm Trichina (*Trichinellidae*).

(3) *Annelida*, the segmented worms including the earthworm (*Lumbricidae*), the leech (*Hirudinidae* and others), Nais (*Naididae*), tubifex (*Tubificidae*), and the marine worm or sandworm. Nereis (*Nereidae*), which is found along the seashore.

Class 1. Chaetopoda (bristle-footed). Annelids with setae.

Order 1. *Polychaeta* (many bristles). Nereis.

Order 2. *Oligochaeta* (few bristles). Earthworm, tubifex, and Nais.

Class 2. *Hirudinea*. The leeches.

The complete classification of worms will be found in Chapter I.

BIBLIOGRAPHY

Worms

Harmer, S. F., and Shipley, A. E., *Worms*. Cambridge Nat. Hist. Series, Vol. II, Macmillan, 1909.

Hegner, R. W., *College Zoölogy*. Macmillan, 1932.

——, *Parade of the Animal Kingdom*. Macmillan, 1935.

Pratt, H. S., *A Manual of the Common Invertebrates*. A. C. McClurg Co., 1929.

(For additional references see bibliographies attached to Chapters I, II, and VIII.)

CHAPTER XI

THE MOLLUSKS OR THE ANIMALS WITH SHELLS

The mollusks include the soft-bodied animals such as snails, slugs, limpets, oysters, clams, mussels, scallops, squids, and octopi. Some of them, such as the snails, slugs, squids, and octopi, have distinct heads; while others, such as clams, oysters, and mussels, are headless. Most of the mollusks secrete shells about themselves as a means of protecting their delicate bodies. The shell may be composed of two halves or valves or it may consist of a single valve. The oysters, clams, and mussels are bivalves, while the snails are univalves. The slug, squid, and octopus do not have shells that cover the entire body; and in many of them the shell is very rudimentary.

The majority of the mollusks are confined to the ocean where they present a wide diversity of size, form, and habits. Some of them are free-swimming; but the majority of them have a feeble, crawling locomotion; while quite a number of them are sessile or sedentary in the adult stage.

In fresh water there are snails, limpets, and mussels. These include many species which are, generally, more or less localized, although many of them are widely distributed; and the mussels, particularly, may range through an entire drainage system due to their parasitic larvae being carried by fishes.

The land mollusks include snails and slugs. The land snails are easily distinguished from the water species. They occur in dead wood, on the bark of trees, on shale banks and rocks, and on the forest floor where there are many minute species that can be collected only by sifting the leaves and débris. The slugs are frequently found in gardens where they sometimes do considerable damage to lettuce and other vegetables; on dead logs and in dead wood; and on the ground under stones and logs.

The water snails are found in ponds usually attached to water plants; in streams, attached to stones, and along the margins where they are attached to sticks and stones; and in lakes where the various species adhere to plants or rocks in the shallow waters

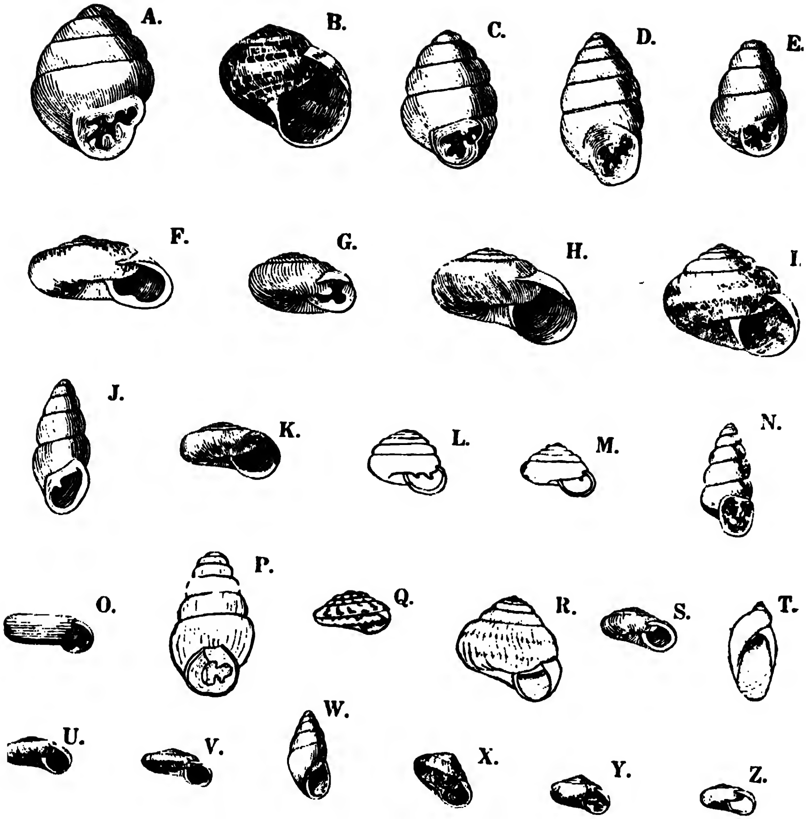


PLATE IV. Land Snails. A. *Vertigo ovata* (*Pupillidae*), length 2.2 mm., diam. 1.5 mm.; B. *Helix aspersa* (*Helicidae*), 22 mm. wide and high; C *Vertigo ventricosa* (*Pupillidae*), length 1.7 mm., diam. 1.1 mm.; D. *Gastrocopta* (*Bifidaria*) *arminifera* (*Pupillidae*), length 4.5 mm., diam. 2.2 mm.; E. *Gastrocopta* (*Bifidaria*) *pentodon* (*Pupillidae*), length 2 mm., diam. 1 mm.; F. *Polygyra profunda* (*Helicidae*), 15 mm. high, diam. 30 mm.; G. *Polygyra fallax* (*Helicidae*); H. *Omphalina cuprea* (*Zonitidae*); I. *Anguispira solitaria* (*Endodontidae*); J. *Carychium exile* (*Carychiidae*); K. *Omphalina inornata* (*Zonitidae*), height 15 mm., diam. 28 mm.; L. *Strobilops labyrinthica vertigo* (*Strobilopsidae*); M. *Strobilops labyrinthica* (*Strobilopsidae*), 1.6 mm. high, 2.1 mm. wide; N. *Gastrocopta contracta* (*Pupillidae*); O. *Halicodiscus parallelis* (*Endodontidae*), height 1.5 mm., diam. 4 mm.; P. *Bifidaria armifera* (*Endodontidae*), length 4.5 mm., diam. 2.2 mm.; Q. *Pyramidula alternata* (*Endodontidae*), height 10 mm., diam. 21 mm.; R. *Pyramidula solitaria* (*Endodontidae*), height 19 mm., diam. 25 mm.; S. *Vailonia costata* (*Valoniidae*), height 1.3 mm., diam. 2.7 mm.; T. *Succinea avara* (*Succineidae*), length 11 mm., width 4.5 mm.; U. *Striature milium* (*Zonitidae*); V. *Gonyodiscus cronkhitei* (*Endodontidae*); W. *Cochlicopa lubrica* (*Cochlicopidae*), height 6 mm.; X. *Hendersonia occulta* (*Helicinidae*); Y. *Ventridens suppressa* (*Zonitidae*); Z. *Zonitodes arboreus* (*Zonitidae*), height 2.75 mm., diam. 5 mm. Courtesy Dr. Stanley T. Brooks, Carnegie Museum.

along the shore. The flat, disc-like, univalvular limpets, which are really snails, are usually found attached to stones in swift water, although certain species inhabit ponds. The mussels are usually found on the bottoms of comparatively fresh ponds, lakes, and slowly flowing streams. Some of the smaller species sometimes adhere to the water plants.

Mussels (*Pelecypoda*). In the larger lakes, ponds, creeks, and rivers, the most conspicuous mollusks are the large mussels or fresh-water clams. They belong to the class *Pelecypoda* which means hatchet foot. Some of these are very large, and they are of commercial importance. The mussels are bivalvular, and the halves or valves are bilaterally symmetrical. The valves are held together at the back by an elastic hinge or ligament. In some common species (*Unio*) the valves articulate with each other by means of interlocking teeth. In another common genus (*Anodonta*) the teeth are absent (Fig. 44).

The visible concentric lines on the outside of the shell are lines of growth, and they indicate the manner in which the mantle secretes and deposits the shell. The protuberance of the shell near the hinge is called the umbo. It indicates the primary area of growth. The shell is composed of three distinct layers; viz., (1) the thin, horny, transparent, outer layer (periostracum) which protects the inner layers from the chemical action of the water; (2) a middle layer of calcium carbonate or lime, the prismatic layer; and (3) an inner lining of mother of pearl, the nacreous layer. The rough margin of the mantle can sometimes be seen around the edges of the shell.

Two siphons, one of which is fringed, are visible on the posterior end of the mussel. The smaller, dorsal siphon is the excurrent one through which all waste matters are discharged. Water containing foodstuffs enters the body through the larger, ventral siphon.

Locomotion is effected by means of a large, fleshy, hatchet-shaped foot which is extended between the partly opened valves at the anterior end. The foot pushes the animal through mud or sand, and a distinct trail is left in passing.

The valves are opened and closed by the relaxation and tension of two large, transverse adductor muscles which hold the valves together. The muscles are attached to the inner surfaces of the valves near their ends. These muscles must be cut by a knife

inserted between the valves before the body of the mussel is exposed for observation. In some species there are distinct differences in the shells of the sexes. When a mussel is opened, the thin, membranous mantle is seen to completely surround the body. It lines both valves of the shell, and its edges secrete the shell along the lines of growth. The mussel breathes by means of two leaf-like gills suspended on each side of the body beneath the mantle. The gills are divided into a series of water tubes by septa or lamellae, and the water is forced through them by means of motile cilia. In the mussels the sexes are separate, and the reproductive organs are located in the fleshy foot. The eggs are withheld within the gill enclosures until they hatch. The larvae are called glochidia (Fig. 45); and they immediately attach themselves to the gills and bodies of fishes where they remain for several weeks, living a parasitic existence. When all of its structures have developed, the larva (glochidium) drops off; and it then leads an independent existence, feeding upon the organic matter carried to its mouth through the ventral siphon. The mantle builds up the shell as the body grows. Because of the parasitic stage, a species may attain a wide distribution, even through an entire drainage system of a large river. Fishes, with their powers of locomotion well developed, migrate a great deal; and they carry the larval mussels into all sections. The blackheads on the gills and bodies of fishes are usually embedded mussel larvae. A parasitized fish is shown in Fig. 46.

The large mussels are used extensively as food by many animals, including man. The shells are also used in abundance for making buttons; and they are raised for this purpose in the flood plains of the Mississippi River and its tributaries. The remnants of the shells are ground and included in chicken feed. They are also used in making fertilizer and in road-making. Pearls are frequently found in the shells of the fresh-water mussels, but they are not as valuable as those of oceanic origin. Pearls are formed by the mollusks themselves. The entrance of worms and foreign bodies causes an irritation which stimulates the secretion of pearly material about them by the mantle. This pearly material is deposited in thin, delicate layers around the object. Some one has said that "the most beautiful and valuable pearl is nothing but the sarcophagus of a lowly worm." The Japanese stimulate a greater pearl production by inserting foreign bodies into the shells of

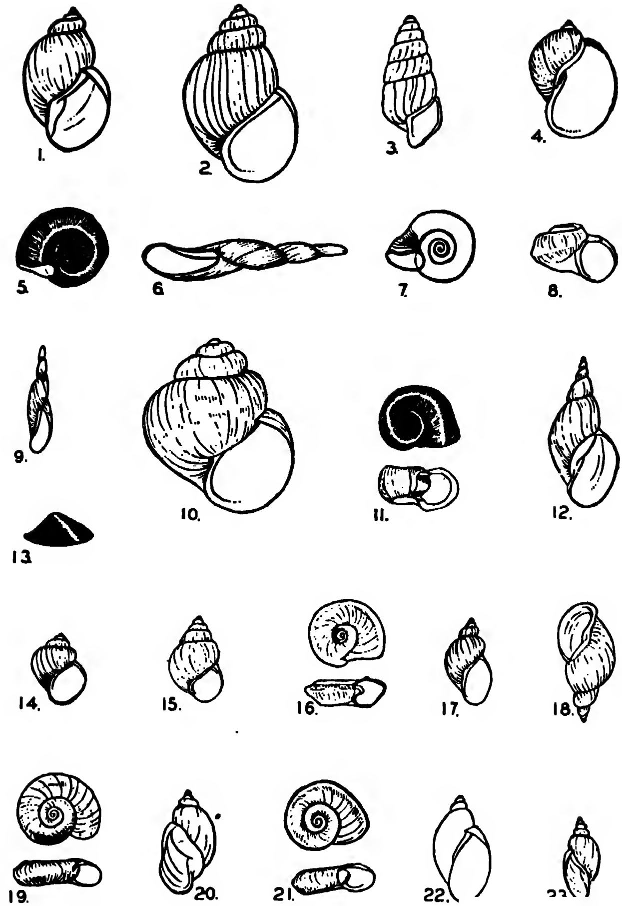


Plate V. Some common water snails. 1. *Lymnaea megasoma* (*Lymnaeidae*); 2. *Campeloma subsolida* (*Viviparidae*); 3. *Pleurocera canaliculatum* (*Pleuroceridae*); 4. *Lymnaea auricularia* (*Lymnaeidae*); 5. *Planorbis trivolvis* (*Planorbiidae*); 6. *Lymnaea haldemani* (*Lymnaeidae*) much enlarged; 7. *Planorbis campanulatus* (*Planorbiidae*); 8. *Valvata tricarinata* (*Valvatidae*); 9. *Lymnaea haldemani* (*Lymnaeidae*); 10. *Viviparous intertextus* (*Viviparidae*); 11. *Planorbis antrosus* (*Planorbiidae*); 12. *Lymnaea stagnalis* (*Lymnaeidae*); 13. *Ancylus rivularis* (*Ancylidae*); 14. *Somatogyrus subglobosus* (*Amnicolidae*); 15. *Bythinia tentaculata* (*Amnicolidae*) Great Lakes; 16. *Planorbis opercularis* (*Planorbiidae*); 17. *Lymnaea abrussa* (*Lymnaeidae*); 18. *Lymnaea palustris* (*Lymnaeidae*); 19. *Planorbis hirsutus* (*Planorbiidae*); 20. *Physa gyrina* (*Physidae*); 21. *Planorbis parvus* (*Planorbiidae*); 22. *Lymnaea columnella* (*Lymnaeidae*); 23. *Aplexa hypnorum* (*Physidae*). Courtesy Dr. Stanley T. Brooks, Carnegie Museum.

pearl oysters. Imitation pearls of a realistic nature are made from fish scales.

There are many species of fresh-water mussels. These are included in three common families in the northeastern and middle Atlantic states. The family *Unionidae* is by far the most abundant and widely distributed. In it there are four common genera: *Unio*, *Anodonta*, *Lampsilis*, and *Alasmidonta*. Other more localized genera are *Obovaria*, *Eurycinia*, *Truncilla*, and *Quadrula*.

The family *Unionidae* is characterized by having equivalve shells with a thick, pearly layer and a dark-colored periostracum. The umbo is located near the anterior end of the body, and the ligament is external and prominent. Hinged teeth are present; but they are not always prominent, and in some species they are apparently absent. The foot is large, and the shell is somewhat variable in shape, according to species. In *Unio*, the thick, oval shell is elongated or rounded in front and pointed behind. Teeth are present and prominent. In *Lampsilis*, teeth are also present; but the ovate shell has distinctly visible radiating rays on the outside. In *Anodonta* teeth are absent, and the shell is thin. In this genus the umbones are inflated or swollen and conspicuous. In *Alasmidonta*, the shell is elliptical and inflated. In this genus the umbones are prominent, and the interior of the shell has a bluish color.

Margaritanidae. Shell large, elongated, with imperfect teeth, and usually black in color. The umbo is not prominent, and the dorso-ventral thickness is less than in the *Unionidae*. The family is distinctly northern, while our native species are eastern. The family does not occur further west than western Ohio where it is rarely found. The common species, *Margaritana margaritifera*, is found in larger creeks and rivers.

In the lakes and ponds there are numerous species of smaller mussels which never attain a large size. They are called finger-nail clams because of their size and shape. The commonest species belong to the family *Sphaeriidae*. They may be found among the water plants or in the bottom material. The common genera are *Sphaerium* and *Pisidium*. Some common mussels are shown in Plate VI.

Snails and slugs (*Gastropoda*). The snails belong to the class *Gastropoda*, which means stomach-footed and is applied because these animals seem to progress on their stomachs. The snails are

univalvular, and they lack the bilateral symmetry characterizing the mussels. The water snails are widely distributed and abundant in ditches, swamps, ponds, lakes, creeks, and rivers. Unlike the mussels, the snail has a distinct head which bears eyes and tentacles. The eyes are located at the base of the tentacles. Most of the water snails have only two tentacles which distinguish them from the land snails which have four. In the snails, the shell is usually coiled; and it also exhibits lines of growth. The coil may be long, spiraled, and pointed; or it may be short and blunt. The shell may coil to the left or right along an axis known as the columella, and snail shells are often referred to as right-handed or left-handed. In the limpets (*Ancylidae*) the shell is a simple, uncoiled, tent-shaped structure on the back of the animal. Snails move along on a flat, fleshy, muscular disc called the foot.

In the upper part of the head is the mouth which contains chitinous jaws; and in the lower part of the mouth there is a muscular ribbon called the lingual ribbon or radula, which is covered with minute, transverse teeth, giving it a rasp-like or file-like appearance. As a snail crawls about on the sides of an aquarium, feeding upon the algae which grow there, it leaves a trail which displays small, transverse waves. These are produced by the teeth on the radula which scrape the plants from the substratum.

There are two main groups of aquatic snails, one of which breathes by means of gills (*Streptoneura*) and the other of which breathes free air through the lungs (*Pulmonata*).

In the pulmonate snails when the body is extended, a breathing aperture or pneumostome can be seen on the side back of the head. These snails come to the surface for air, and they extend the pneumostome above the surface film of the water to inhale.

In the gill-bearing snails, the foot bears a plate-like disc called the operculum which closes the opening of the shell when the body is withdrawn. All snails secrete a mucus over which they travel.

Most aquatic snails lay eggs. These are deposited in kidney-shaped masses of clear, transparent jelly. The eggs at first appear as milky dots distributed throughout the jelly. The masses are seldom more than two centimeters long in the common species, although in the *Ampullariidae* of southern waters the egg masses are quite large. The egg masses are attached to plants, sticks, or stones. Floating boards in still pools may have hundreds of egg

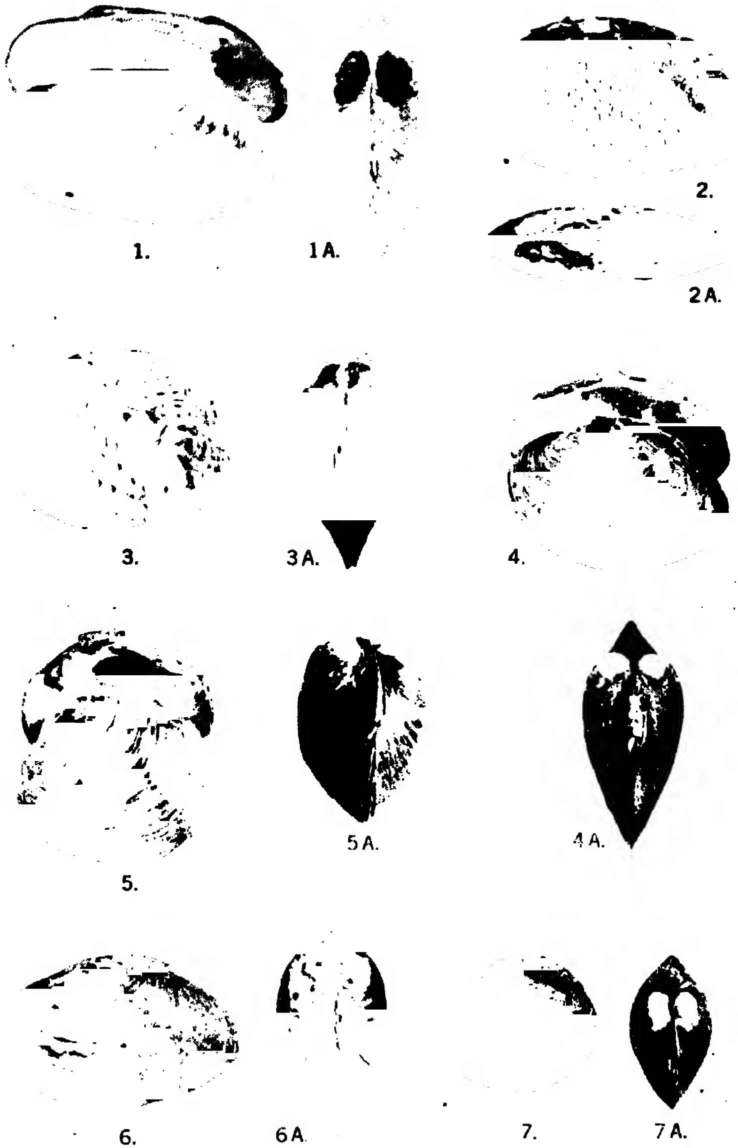


PLATE VI. Common fresh-water mussels. 1., 1A. *Lampsilis luteola*; 2., 2A. *Quadrula verrucosa*; 3., 3A. *Quadrula sp.*; 4., 4A. *Lampsilis ovata*; 5., 5A. *Lampsilis orbicula*; 6., 6A. *Lampsilis fasciola*; 7., 7A. *Obovaria subrotunda*. After Ortmann, *Mem. Carnegie Mus.*

masses on the undersides in the spring. Water snails placed in an aquarium deposit their eggs on the sides where their development can be watched from day to day through a magnifying glass. One family of water snails, however, the *Viviparidae*, is viviparous and brings forth living young. The shells of a number of species representing these common families, *Lymnaeidae*, *Physidae*, *Planorbiidae*, *Valvatidae*, *Viviparidae*, *Pleuroceridae*, *Amnic lidae*, and *Ancylidae*, are shown in Plate V.

The limpets (*Ancylidae*) are flattened, cone-shaped snails with a broad, oval foot. Their shells lack the coil which other snails have. They are found attached to smooth rocks in streams and ponds. All of the aquatic snails are herbivorous, feeding upon algae and other plants. The families are differentiated upon the bases of the teeth on the radula; the nature of the coil, spire, suture, opening, and lip of the shell; and the presence or absence of an operculum and the character of the operculum when present.

The *Physidae*, *Planorbiidae*, *Lymnaeidae*, and *Ancylidae* have no operculum; but in the *Valvatidae* and *Viviparidae* an operculum is present. In the *Planorbiidae* the shell is coiled horizontally; and it is therefore somewhat flattened on its sides. In the *Physidae* the shell coils to the left, and in the *Lymnaeidae* it coils to the right. There are nine families of water snails. A brief summary of family characters will help in their ready identification.

(1) *Lymnaeidae.* Pulmonate snails with a thin shell. Shell higher than wide and composed of from four to seven whorls, usually with an acute spire. The aperture is large, often flaring, with a simple, acute lip. Color from yellowish-green to black. The coil is to the right. Common in ponds and streams.

(2) *Physidae.* Pulmonate snails with thin shell and an acute spire. The shell is composed of four to eight whorls. The body whorls large and higher than spire. The whorls in the spire are small. The aperture is oval and large with an acute lip. Common in ponds, ditches, lakes, and streams.

(3) *Planorbiidae.* In these pulmonate snails the shell is coiled horizontally, and it is almost discoidal and flattened on the sides due to the greatly depressed spire, which may even be sunken in some species. The lip is variable, and the aperture is rounded and large. Common in lakes, ponds, and streams.

(4) *Ancylidae.* Pulmonate snails with thin, slightly elongated, tent-shaped or conical shell. Shell not coiled or spiraled, and the

apex is not in the center of the elevation. Common in some sections in brooks and ponds, usually attached to smooth stones.

(5) *Amnicolidae.* Operculate, gill-bearing snails with small, thin, smooth shells which are usually elongated and conical. Spire short and pointed. Body whorl much higher than spire. Eastern genera *Bythinia, Stomatogyrus,* and *Paludestrina.* The genus *Amnicola* is more common in the central states.

(6) *Viviparidae* (*Paludinidae*). Operculate, viviparous, gill-breathing water snails with conical or globose shell having rounded whorls. The aperture is large, simple, rounded, or ovate. The operculum is not spiraled; and the shell is rather solid. Found in lakes and rivers.

(7) *Valvatidae.* Operculate snails with a small, greenish, conical, and depressed, almost discoidal, shell. Umbilicus open. Operculum circular and spiraled. Lakes and streams.

(8) *Pleuroceridae.* Operculate snails with much elongated shells. In these the spire is very high. The shell is much longer or higher than wide, with numerous whorls. Operculum spiraled. Aperture rounded or ovate, channeled, or angulate in front. Size from 20 to 30 mm. The genus *Pleurocera* is common in rivers toward the South. *Goniobasis* is abundant in the Great Lakes.

(9) *Ampullariidae.* These are the largest of American water snails. Mostly southern and tropical. Operculate snails with medium shell. Shell usually with four whorls. Spire low. Body whorl and aperture very large. Color yellowish-green with inconspicuous, dark, revolving bands. Found in rivers and lakes from Georgia southward.

The land snails. Most of the land snails have two pairs of retractile tentacles. Posterior tentacles are the larger, and the eyes are borne on their tips. The respiratory opening or pneumostome is located on the right side of the body back of the head.

There are 13 families of terrestrial snails in the eastern section of the United States. Many of these are very minute species that live among the fallen leaves and débris on the ground where they are difficult to see and to find. Many of them are also difficult to identify in the field because of their size. As a rule, these small species escape the observation of most people; and only those who are sufficiently interested in the land snails of a region and who might choose the problem of recording the local

species would be likely to pay much attention to them. In field studies, however, the student is certain to encounter some land snails which are fairly large and conspicuous.

Most of the land snails lay eggs which are deposited in dead logs, in the ground, or under stones and logs. While some species are carnivorous and feed upon other animals, the majority of them are herbivorous and live upon decaying wood or upon green plants.

A few native species have an operculum; and in periods of drouth the body is withdrawn into the shell, and the aperture is closed by the operculum. In winter, the terrestrial snails hibernate in crevices in the ground, in hollow logs, under the bark of trees and recumbent logs, or under stones. Quite a number of them are capable of burrowing into soft earth. Snails have salivary glands, and they secrete a mucus on the surface over which they move. In the species which do not have an operculum, the aperture of the shell is covered during aestivation and hibernation with a thin film of secreted material which becomes hardened.

The land snails should be collected and identified as far as families. The most common and conspicuous species such as those of *Polygyra* can easily be determined by using the references suggested. The family *Testacellidae* is not an American family, but it is found so often in greenhouses and in landscaped yards, often in the ground, that it seemed best to include it here. The land snails are indicated by the following families:

(1) *Pupillidae.* These are small, often minute snails with cylindrical or conical blunt multispiral shells. The aperture of the shell is very small, and the body whorl is not over half as high as the entire shell. They are found under decaying wood and leaves in moist places.

(2) *Cochlicopidae.* In these the shell is elongate, yellowish in color, slender, and conical. The aperture is rounded and without teeth. They are about 6 mm. high and have six whorls. The body whorl is more than half the total height. They are found under débris on the ground.

(3) *Valloniidae.* These are minute snails with low, depressed spiral. They are usually less than 2 mm. in height. The aperture is without teeth. One native species, *Vallonia pulchella*, measures 1.3 mm. in height and 2.6 mm. in diameter. It is light-colored, transparent, and smooth. Another native species, *V. costata*, is

gray with regular transverse ribs. It is 1.3 mm. high, and its diameter is 2.7 mm.

(4) *Succineidae.* In this family the shell is thin with a small spire and with a large aperture. The body whorl is much higher than the spire. As a rule the shell does not cover the entire body when it is withdrawn.

(5) *Helicidae.* In these the shell has a low, conical spire consisting of from five to seven whorls. Some species have teeth in the aperture, and most of them have a wide lip. The teeth are important in specifying the members of the genus *Polygyra.* The aperture is closed by an operculum when the body is withdrawn. The Helicids are among our most common terrestrial snails. The European edible snail, *Helix pomatia,* belongs to this family.

(6) *Endodontidae.* The shell in these is conical or depressed, ribbed, and striated with brown. The lip is thin and sharp. These snails have pedal grooves. They are common under logs and leaves.

(7) *Circinariidae.* The members of this family are mostly confined to the Pacific slope; but there is one medium-sized species, *Circinaria concava,* found in the eastern states. It measures 8 mm. in height and 17 mm. in diameter. This species is carnivorous, feeding upon larvae, worms, and other snails.

(8) *Zonitidae.* These are usually small snails found under leaves and rotting logs in moist places. The shell is thin and delicate, and the aperture has a sharp lip. The various species are frequently smooth and shining. Size from one-half mm. to three mm. in height.

(9) *Strobilopsidae.* In these the shell is heliciform and composed of five or six striated whorls. The aperture has prominent lamelliform teeth, and there is no operculum present. Most of them are less than 2 mm. high. Found on the ground among dead leaves.

(10) *Carychiidae.* These are terrestrial snails in which the shell is higher than wide and averaging about 2 mm. in height. The shell is thin and elongated, resembling an insect pupa. There are usually one or two teeth present in the aperture. No operculum is present. The family is largely European, although there are a few native species. They are found on the ground among leaves and débris.

(11) *Helicinidae.* Only one species of this family occurs in our fauna, and it is more common in the southern states. The shell

is conical or depressed and heliciform. An oval and sometimes triangular operculum is present. The native species, *Helicinia orbicula*, is yellowish with spots frequently present on the shell, which is composed of five whorls. It is 6 mm. high and 9 mm. in diameter.

(12) *Haplotrematidae.* There is only one species of this family in our fauna. The shell is higher than wide and completely covers the body of the animal. No operculum is present. The lip of the aperture is thickened, and no teeth are present. The shell is whitish. *Haplotrema concava.*

(13) *Testacellidae.* A family which comprises mostly exotic species, although there are several species in southern United States. One exotic species, *Testacella halictoidea*, is frequently found in greenhouses and in the ground where shrubbery has been planted and taken care of. In this family the shell is variable. The body is long and slug-like; and the radula is equipped with thorn-like teeth. In most species the shell is rudimentary and ear-shaped, although in the southern genus *Euglandina*, the shell is long, slender, and conical in shape; and it has six to eight whorls. In the imported greenhouse species the shell is about $4\frac{1}{2}$ mm. broad and about 7 mm. high; but the body is five times as long as the shell. These snails feed upon other snails, insect larvae, and worms.

(14) *Bulimulidae.* This is a southern family which has a thin, elongated, conical shell with a high spire and composed of six or seven whorls. The body whorl is longer than the spire. The aperture is elongated and without teeth. Size 1.5 cm. to almost 2 cm. in length. A number of native species of land snails representing the various families is shown in Plate IV.

The slugs. The slugs are terrestrial mollusks with an elongated body that tapers posteriorly. None of them has a shell that covers the entire body as in the snails; but a rudimentary shell in the form of a thin, calcareous plate is present in the mantle of most species. The mantle seldom extends as far as the middle of the body, and in some species it is quite small. In the common garden slug, *Philomicus*, however, the mantle is large, covering almost the whole body. Slugs inhabit moist places on the ground, and they are frequently found in decaying wood, on the bark of trees, and on green plants. Slugs deposit their eggs in the soil, under stones, or in decaying wood. All of them are nocturnal, and they

can be found during the day by turning over stones and logs, also in crevices of bark. When disturbed or placed in alcohol or water, they discharge a copious supply of slimy mucus. There are three principal families of slugs in the United States.

The *Limacidae* include the large gray *Limax maximus*, which has rows and stripes of feeble black on the dorsal surface of the body. The underside is dirty white. The body is covered with coarse, elongated tubercles. The mantle covers a small section of the back behind the head. It is about 16 cm. in length and is the largest of our native species. It was originally introduced from Europe.

Another member of this family is the small black *Agriolimax* (*Agrestis*) *campestris*, which is common under damp leaves and on green plants. It is sometimes very destructive to growing lettuce. It is about 2.5 cm. in length.

In the family *Arionidae*, the yellowish-gray or black slug, *Arion hortensis*, measuring about 5 cm., is the only eastern representative.

The family *Philomycidae* is distinguished from the others by the fact that there is no rudiment of a shell, and the mantle covers the entire back. The body is considerably elongated and tapers gradually toward the posterior end. There is no caudal mucous pore in this group. The respiratory pore is on the right side back of the head. The common species, *Philomicus carolinensis*, is whitish with dark spots and blotches. It is found in trees, under bark, and occasionally in rotten wood. The species is partial to the linden tree, and it is about 7 cm. in length.

Some marine mollusks are described in the chapter on animals of the ocean beach. The following key will be useful in the quick identification of the families of land snails.

KEY TO THE FAMILIES OF LAND SNAILS OF NORTHEASTERN NORTH AMERICA[1]

I. Visible shell present

A. Aperture closed by an operculum when the body is withdrawn into the shell . . . . . . Family *Helicinidae* Genus *Hendersonia* Species *occulta* *

AA. Aperture not closed by an operculum

[1] This key was especially prepared for this book by Dr. Betty Watt Brooks and Dr. Stanley T. Brooks of the Carnegie Museum.

B. Shell completely covering the body of the animal
 C. Shell wider or as wide as high
  D. Lip of aperture thickened, reflected, or flared; animal without pedal grooves
   E. Less than two millimeters in altitude
    F. With prominent lamelliform teeth within the aperture; running spirally and parallel to the body whorl............Family *Strobilopsidae*
    FF. Without teeth.............Family *Valloniidae*
   EE. More than two millimeters in altitude
    F. Strongly reflected lip; may have from one to four denticles in aperture or toothless Family *Helicidae*
    FF. Never strongly reflected; a whitish-gray shell without teeth { Family *Haplotrematidae* Genus *Haplotrema* Species *concava* *
  DD. Lip of aperture thin; animal with pedal grooves
   E. Thin, shining, and polished......Family *Zonitidae*
   EE. Not so thin, heavily ribbed to slightly striate; with dark color. May have solid color, bands, or flammules of reddish-brown...Family *Endodontidae*
 CC. Shell higher than wide
  D. Over two millimeters in altitude and rarely over seven
   E. Body whorl over one-half as high as entire altitude Family *Cochlicopidae*
   EE. Body whorl not over one-half as high as entire altitude.....................Family *Pupillidae*
  DD. Not over two millimeters in altitude Family *Carychiidae*
BB. Shell not covering entire body when animal is retracted
 C. Shell thin, aperture very large, spire small, body whorl much longer and higher than spire. Semi-aquatic Family *Succineidae*
 CC. Shell rudimentary, ear-shaped, located on the posterior extremity of the body...............Family *Testacellidae*

II. Shell lacking or internal; the *slugs*
 A. Mantle reduced to fleshy pad on the back (anteriad)
  B. Tail keeled.............................Family *Limacidae*
  BB. Tail not keeled; the mantle farther forward on the body Family *Arionidae*
 AA. Mantle covering the entire body to the edge of the foot Family *Philomycidae*

* Only one genus and species represented in northeastern North America.

BIBLIOGRAPHY

Mollusks

Allen, W. R., *Studies of the Biology of the Freshwater Mussels.* Proc. Ind. Acad. Sc., 1921, pp. 227–238.

Baker, F. C., *The Molluscan Fauna of Western New York.* Trans. Acad. Sci., St. Louis, Vol. VIII, No. 5, 1898.

——, *The Mollusca of Indiana.* Indiana Dept. Geol. and Nat. Resources, 1899.

——, "A Revision of the Physae of Northeastern Illinois," *Nautilus*, Vol. 14, 1900.

——, *The Mollusca of the Chicago Area*, Parts 1 and 2. Bull. Ill. Nat. Hist. Survey, Snails and Mussels, 1902.

——, *Shells of Land and Water.* A. W. Mumford, Chicago, 1903.

——, *A Catalogue of the Mollusca of Illinois.* Bull. Ill. State Lab. Nat. Hist., Vol. VII, Art. VI, 1906.

——, *The Ecology of the Skokie Marsh Area with Special Reference to the Mollusca.* Bull Ill. State Lab. Nat. Hist., Vol. VIII, Art. IV, 1910.

——, *Lymnaeidae of North and Middle America.* Chicago Acad. Sci. Spec. Pub. No. 3, 1911.

——, *Mollusca; Biological Survey of the Sand Dune Region of the South Shore of Saginaw Bay.* Mich. Geol. and Biol. Surv. Pub. 4, Biol. Ser. No. 2, 1911.

——, *The Relation of Mollusks to Fish in Oneida Lake.* Tech. Pub. No. 4, Vol. 16, N. Y. State College of Forestry, 1916.

——, *The Productivity of Invertebrate Fish Food on the Bottom of Oneida Lake with Special Reference to Mollusks.* Tech. Pub. No. 9, Vol. 18, N. Y. State College of Forestry, 1918.

——, "The Molluscan Fauna of the Big Vermillion River, Ilbnois," *Ill. Biol. Monthly*, Vol. VII, No. 2, 1922.

——, *The Fresh Water Mollusca of Wisconsin.* Wis. Geol. and Nat. Hist. Survey Bull. No. 70, 1928.

Bartsch, Paul, *American Shipworms.* U. S. Nat. Mus. Bull. 122, 1922.

Binney, W. G., *Land and Fresh Water Shells of North America.* Part II, Smithson. Misc. Coll., 1865, Vol. 7, No. 143, p. 172; Part III, No. 144, p. 128.

——, *Manual of American Land Shells.* U. S. Nat. Mus. Bull. 28, 1885.

Churchill, E. P., and Lewis, S. L., *Food and Feeding in Fresh-water Mussels.* Bull. U. S. Bur. Fish, Vol. XXXIX, Doc. No. 963, 1924.

Clark, A. H., *Animals of Land and Sea.* Van Nostrand, 1925.

Coker, R. E., *Mussel Resources of the Tensas River of Louisiana.* U. S. Bur. Fish. Econ. Bull. 14, 1913.

Coker, R. E., *The Common and Scientific Names of Fresh-water Mussels.* U. S. Bur. Fish. Econ. Bull. 15, 1915.

Cooke, A. H., *Mollusca.* Cambridge Nat. Hist. Ser., Vol. III, Macmillan, 1913.

Crandall, O. A., "The American Physae," *Nautilus,* Vol. 15, 1901, Nos. 3, 4, 5, 6.

Crowder, William, *Between the Tides.* Dodd Mead, 1923.

Dakin, W. J., *Pearls.* Cambridge Univ. Press, 1913.

Dall, W. H., *Preliminary Catalogue of the Shell-bearing Molluscs.* U. S. Nat. Mus. Bull. 37, 1889.

Forbes, S. A., and Richardson, R. E., *Studies on the Biology of the Upper Illinois River.* Bull. Ill. State Lab. of Nat. Hist., IX, 1913, pp. 481–574.

Goodrich, Calvin, *The Anculosae of the Alabama River Drainage.* Univ. of Mich. Mus. of Zoöl. Misc. Pub. No. 7, 1922.

——, *The Genus Gyrotoma.* Univ. Mich. Mus. of Zoöl. Misc. Pub. No. 12, 1924.

Hegner, R. W., *College Zoölogy.* Macmillan, 1933.

——, *The Parade of the Animal Kingdom.* Macmillan, 1935.

Henderson, J. B., *East American Scaphopod Molluscs.* U. S. Nat. Mus. Bull. 111, 1920.

Isely, F. B., *Preliminary Note on the Ecology and Juvenile Life of the Unionidae.* Biol. Bull., Vol. 20, 1911.

Lancaster, E. R., *A Treatise on Zoölogy,* Part V. A. and C. Black, 1906.

Lefevre, G., and Curtis, W. C., *Studies of the Reproduction and Artificial Propagation of Fresh Water Mussels.* Bull. Bur. of Fish., Vol. 30, 1910.

Morgan, Ann, *Field Book of Ponds and Streams.* Putnam, 1930.

Needham, J. G., and Needham, Paul R., *Guide to the Study of Fresh Water Biology.* Amer. Viewpoint Soc., 1927.

Ortmann, A. E., *A Monograph of the Najades of Penna.* Mem. Carnegie Mus. No. 4, 1911.

——, *Notes upon the Families and Genera of Najades.* Ann. Carnegie Mus., Vol. VIII, 1912.

Parker, T. J., and Haswell, W. A., *Textbook of Zoölogy,* Part I. Macmillan, 1928.

Pilsbry, H. A., "A Classified Catalogue of American Land Shells with Localities," *Nautilus,* Vol. XI, 1897.

Pilsbry, H. A., and Vanatta, E. G., *A Revision of North American Slugs.* Proc. Phila. Acad. Sci., 1898.

Pratt, H. S., *Manual of the Common Invertebrates.* A. C. McClurg Co., 1929.

Prime, Temple, *Monograph of American Corbiculidae.* Smithson. Misc. Coll., Vol. 7, 1865, No. 145, pp. 192.

Rogers, Julia, *The Shell Book*. Macmillan, 1909.
Schick, M., "Molluscan Fauna of Philadelphia," *Nautilus*, Vol. VIII, 1895.
Simpson, C. T., *The Classification and Geographical Distribution of the Pearly Fresh Water Mussels*. Proc. U. S. Nat. Mus., Vol. XVIII, 1896, pp. 295–343.
——, *A Descriptive Catalogue of the Naiades or Pearly Fresh Water Mussels*. Bryant Walker, Detroit, 1914.
Surber, T., *Identification of the Glochidia of Fresh-water Mussels*. U. S. Bur. Fish., Doc. 813, 1915.
Tryon, G. W., *Land and Fresh Water Shells of North America*. Smithson. Misc. Coll., Vol. V, No. 16, 1873.
——, *A Manual of Conchology*. Phila. Acad. Nat. Sci., 1878.
Walker, Bryant, *An Illustrated Catalogue of the Mollusca of Michigan*. State Board Geol. Survey, 1905.
——, *Annotated List of the Mollusca of Isle Royale, Michigan*. Reprinted from Annual Rept. Geol. Survey of Mich., 1908.
——, *A Synopsis of the Classification of the Fresh-Water Mollusca of North America North of Mexico*. Univ. Mich. Mus. Zoöl. Misc. Pub. No. 6, 1918.
——, *The Terrestrial Shell-bearing Mollusca of Alabama*. Univ. Mich. Mus. Zoöl. Misc. Pub. No. 18, 1928.
Ward, H. B., and Whipple, G. C., *Fresh Water Biology*. John Wiley and Sons, 1918.
Ward's Natural Science Establishment. *Shell Catalogue*.

CHAPTER XII

THE ARTHROPODS (MYRIAPODS, SPIDERS, CRUSTACEA, AND INSECTS): HOW TO DISTINGUISH AMONG THEM

The Arthropods, with four common classes including insects (*Insecta*); spiders, mites, ticks, scorpions (*Arachnida*); millipedes, centipedes (*Myriapoda*);[1] and crayfishes, lobsters, crabs, barnacles, and shrimps (*Crustacea*), constitute the largest group of animals on earth.

All of them are bilaterally symmetrical, and their bodies are composed of a varying number of rings or segments, many of which bear paired appendages. Their bodies are covered with an external skeleton of a complex, insoluble substance known as *chitin*. This skeleton, which is secreted by cells in the body wall, is shed from time to time during the growth period, the process being known as molting or *ecdysis*. Since the chitinous skeleton is a lifeless, inflexible substance, the shedding of it is necessary to allow increase in size. A number of arthropods, notably the crustaceans and the spiders, are capable of regenerating lost structures, such as legs and antennae, during the growth period and up to the time of the final molt.

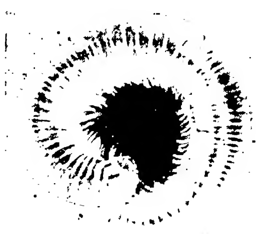


FIG. 50. A millipede (*Spirobolus*).

The phylum includes an assortment of diverse individuals which exhibit marked differences in size, appearance, and structural modifications. However, there are pronounced similarities within each class and fundamental differences among the various classes, so that they may be readily distinguished and identified.

Distinct and unmistakable characters are obvious, and these facilitate the field identification of class members. Among these characters are: (1) the number of visible body segments, (2) the

[1] The recent classification separates the centipedes and millipedes into two classes—Chilopoda and Diplopoda.

number of body regions, (3) the number, kinds, and positions of the eyes, (4) the number of pairs of antennae, (5) the number, arrangement, and adaptive radiation of other appendages.

In the higher crustaceans (*Decapoda*), the head and thorax are fused together forming a *cephalothorax,* to which is attached the distinctly segmented abdomen. While the cephalothorax is a solid piece, the head region is marked by a cervical groove. These regions are not pronounced or present in many of the lower crustaceans.

In the Arachnida (although the mites and ticks have only one body region), a cephalothorax is also present; but in these (spiders) the abdomen is not segmented in any of our native species. In spiders the abdomen is considerably larger than the cephalothorax, as a rule. In the Myriapods there is a great number of distinct body segments (25–173), but the thoracic region is not pronounced.

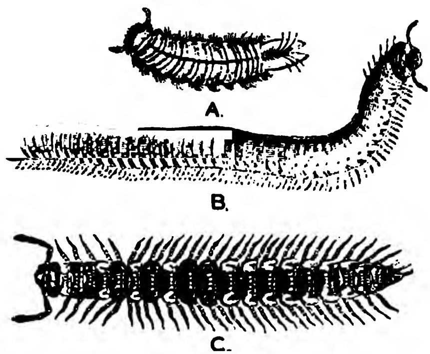


Fig. 51. Millipedes. A. *Polyxenes lagurus* (*Polyxenidae*); B. *Julus nemorensis* (*Julidae*); C. *Polydesmus collaris* (*Polydesmidae*). From Hegner, *College Zoology.*

In the insects (excepting the most primitive ones), three distinct body regions — head, thorax, and abdomen—are visible. The abdomen is distinctly segmented.

In the Decapod crustaceans there is a single pair of compound eyes. Many Myriapods are blind, but a number of them have simple eyes which may occur as a single pair or they may be aggregated in clusters. The spiders, as a rule, have eight simple eyes or ocelli. These are arranged in a definite pattern on the anterior margin of the cephalothorax. The position of these ocelli and their arrangement in two or three rows will be according to species and habits. The pattern arrangement of the ocelli is of great value in identifying individuals.

Although some insects, such as termites and cave-inhabiting forms, are blind, most insects have one pair of compound eyes and usually three simple eyes. The arrangement of ocelli and the position of the compound eyes are quite variable in different species.

In the beetles the ocelli are usually absent. In some insects such as May flies and whirligigs the compound eyes may be wholly or almost completely divided, so that there may appear to be two pairs.

The crayfish has two pairs of antennal structures attached to the head. One pair, the antennae, is quite long; and the other pair, which is smaller, is situated between the eyes. These are the *antennules*. Both are doubled or *biramous*. The myriapods and insects have but a single pair of antennae which, particularly among the insects, are extremely variable in length and form. In the Arachnida the antennae are lacking.

While vast modifications occur in the appendages of arthropods, they are reliable means of placing members in their proper classes. Appendages include mouth parts, antennae, eyes, wings, swimmerets, genitalia, cerci, caudal filaments, and legs. For purposes of classification it is sufficient to consider only the legs.

In the crayfish all of the twenty body segments bear pairs of appendages, which are biramous or forked. In the crustaceans, as a class, these appendages are modified to serve as sense organs, seizing organs, gills, swimmerets, or legs. In the crayfish there are five pairs of legs (*Decapoda*) attached to the cephalothorax. As explained elsewhere, the first pair is not used for ambulatory purposes. In the myriapods the number of legs is great, almost every segment bearing at least one pair of legs. In the arachnids there are four pairs of legs attached to the thoracic region of the cephalothorax. The abdomen bears no leg-like appendages.

In insects three pairs of legs are present (*Hexapoda*), and these are attached to the middle body region or thorax.

Only the insects have wings. Although there are a number of wingless kinds, the great majority of insects possess one or two pairs of wings which are also attached to the thorax.

As will be seen later, there is a remarkable adaptive radiation in the appendages of arthropods. Legs may be used for walking, crawling, running, jumping, swimming, digging, and seizing. Wings are modified for flying, soaring, balancing, protective coverings, and music-making. Leg-like appendages, all of which are homologous to true legs, are modified for swimming, breathing, copulatory processes, and poison glands. Mouth parts are adapted chiefly to biting, chewing, and sucking, with all sorts of variations of these processes. Antennae are also variable in size, form, in-

sertion, and function, being adapted to hearing, smelling, feeling, breathing, communicating, and even to holding the opposite sex. Many of these adaptations are described in the discussions of the various groups.

The Centipedes and Millipedes

The "thousand-legged worms," as the centipedes and millipedes are called, are distantly related to the spiders, insects, and crayfishes. They may be distinguished from all other arthropods, however, by their numerous body segments and legs. While the name *millipedes* (L. "1000 feet") would indicate that these creatures have more leg-bearing segments than the *centipedes* (L. "100 feet"), there are some centipedes which have a greater number of body segments than some millipedes. In our common native forms, however, the centipedes as a rule have fewer body segments and, therefore, a lesser number of legs than the millipedes. All of the myriapods breathe by means of tracheal systems similar to those in insects.

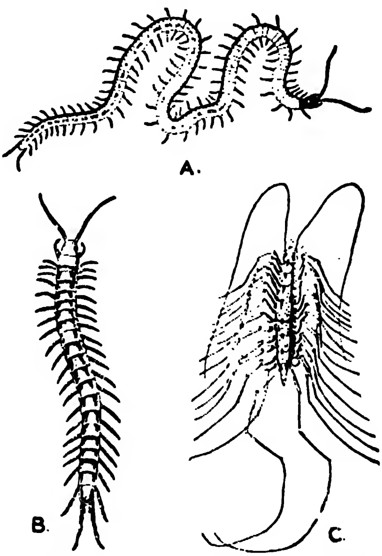


Fig. 52. Centipedes. A. *Geophilus longicornis* (*Geophilidae*); B. *Scolopendra morsitans* (*Scolopendridae*); C. *Scrutigera forceps* (*Scrutigeridae*). From Hegner, *Invertebrate Zoology*.

The centipedes (subclass *Chilopoda*) (Fig. 52) are usually swift-moving animals, while the millipedes move rather slowly, as a rule. The centipedes are entirely carnivorous, feeding upon snails, worms, insect larvae, and other small animals, which are killed by a pair of poison claws or maxillipeds which are located upon the segment just back of the head. The poison claws are, in reality, modified legs. Each body segment, excepting the head, the one bearing the claws, and the last two, bears a pair of legs. Among certain species, however, the young are not born with a full number of legs.

The centipedes have one pair of rather long antennae, and in some species the eyes are wanting. When eyes are present, they

are simple eyes or ocelli, similar in appearance to the ocelli of insects; and they range in number from one to many. The ocelli are arranged in groups or clusters similar to the aggregate eyes of certain primitive insects.

Our common centipedes may be readily distinguished from the millipedes by their fewer body segments; by their dorso-ventrally flattened bodies; and by their long antennae. Each segment bears a *single* pair of legs which are attached to the ventral side of the segment *toward the outer margin and away from the mid-ventral line.*

There are many more or less common species of centipedes, representing four families, in the United States. While centipedes are generally feared because they are thought to be deadly poisonous, none of our common species is dangerous at all; and the common fear of them is unjustified. The larger, tropical species are the only ones that can inject sufficient poison to be of serious consequence.

Perhaps the most commonly found species, the skein centipede (*Scutigera forceps*—fam. *Scutigeridae*) is an inhabitant of households where it lurks in cellars and dark closets. It is a rather grotesque-looking, grayish, very long-legged, and swift-moving creature which usually creates quite a scene when it is discovered by the timid housewife. The body, which is composed of fifteen segments, hangs low; and the antennae are quite long. The last pair of legs is much longer than the others, and they are apparently used as caudal feelers. The skein centipede is quite harmless and is really an addition to the household since it feeds upon insects such as bedbugs and roaches, pill bugs, and other vermin which infest buildings.

Most of the centipedes inhabit woodland areas where they may be found under stones and under bark and especially in dead, recumbent logs.

The family *Geophilidae* is represented by six or seven species in middle and eastern United States. Of these, *Geophilus longicornis*, a long, slender, blind species with more than 30 body segments and with 14 jointed antennae, and *Geophilus rubens* are the most common. The latter has a wide body and a wider head. It is about 45 mm. long with fifty or more pairs of legs, the last pair only slightly longer than the others. The color is usually orange in the anterior region and somewhat darker over the rest of the body.

The family *Lithobiidae* is characterized by 15 leg-bearing seg-

ments, 9 of which are large and 6 small. The eyes are usually composed of many ocelli. Two common species, *Lithobius forficatus* and *L. multidentatus*, are common. The former is yellowish or brownish with antennae half as long as the body and composed of from 33 to 43 segments. *L. multidentatus* is about 25 mm. long with shorter antennae. The antennae have from 19 to 23 joints, and the ocelli number from 27 to 35.

The most common woodland species belongs to the family *Scolopendridae* to which belong the most poisonous centipedes. In woodland areas, under bark on dead logs, may be found a reddish-brown centipede (*Scolopcryptos sexspinosa*), which has from 21 to 23 segments. The antennae have from 17 to 31 segments.

While some members of this family are blind, the commonest species (*Scolopendra morsitans*) has eyes and 21 pairs of legs. All of the centipedes lay eggs in the ground or in soft, dead wood. The genital organs are located at the posterior end of the body.

The millipedes (subclass *Diplopoda*) (Fig. 51) have from 25 to more than 100 body segments, and the body form is usually subcylindrical which contrasts it with the flattened bodies of centipedes. Each leg-bearing segment bears *two* pairs of legs which are attached close to the mid-ventral line. When the common millipede is disturbed, it rolls itself into a coil where its hard, chitinous covering protects it from most enemies.

The antennae are short and somewhat club-shaped. Simple eyes or clusters of ocelli are present according to species. The millipedes eat decaying wood, and a few of them feed upon growing plants. The genital organs are located at the base of the legs on the second and third body segments. Eggs are laid in rich, damp earth. The millipedes breathe by means of a tracheal system, and the spiracles are unevenly distributed on the body. All of the millipedes are harmless, although many of them possess stink glands which discharge an offensive gas which sometimes contains hydrocyanic gas.

The diplopods are represented in the United States by six families which contain more than 100 species.

The commonest millipedes belong to the family *Julidae*, the members of which have cylindrical bodies composed of from 30 to 70 segments. *Julus virgatus* is a common species everywhere in meadows and gardens. It is a short species, yellowish brown in color with a median and two lateral bands. *Spirobolus marginatus* is also very common, and it is much more readily noticed because

of its size and color. The body measures about ten centimeters. It is reddish-brown with a reddish-yellow ring on each segment. It has almost 100 pairs of legs.

The *Polydesmidae* are broad and somewhat flattened millipedes composed of 19 or 20 segments. The dorsal plate of each segment is somewhat extended so as to form a conspicuous wing. One genus is more or less common in the eastern and central states. *Polydesmus* has two or three transverse rows of tubercles on each segment, and the stink pores are surrounded by elongated swellings. The color is usually reddish or brownish. *Polydesmus serratus* is the commonest species.

The family *Polyxenidae* have 11 segments. Their bodies are soft, small, short, and lack the stink glands. On the side of each segment there is a bunch of conspicuous hairs. One species, *Polyxenus fasciatus*, is pale brown with white feet. It is about 2.5 mm. long.

The family *Craspedosomidae* resemble the *Julidae*, but they lack stink glands. One species, *Campodes flavicornis*, is about 15 mm. long and is composed of 30 segments. It has long, slender antennae and prominent, triangular eyes. The color is yellowish brown.

The family *Lysiopetalidae* are also like the *Julidae*, but differ in that only the first pair of legs on the seventh segment is copulatory. One species, *Lysiopetalum lactarium*, has a wide distribution. Its body is composed of about 60 segments, and it has 115 pairs of legs. The color is yellowish brown with darker bands.

The family *Polyzoniidae* is mostly restricted to the central states. The long, wide, slightly flattened body consists of from 30 to 100 segments. The commonest species is *Polyzonium rosalbum*, which has about 50 segments. It is reddish brown in color, paler along the posterior margins of the segments. The antennae, which are very dark, are close together; and stink glands are present.

Under stones in moist woods are found minute (1.3 to 2.7 mm.) animals which may correctly be included in the *myriapoda*. One group, the *Symphyla*, contains colorless, centipede-like animals composed of 14 segments and with 12 pairs of legs. The other group, the *Pauropoda*, have elongated, cylindrical bodies composed of 12 segments and 9 pairs of legs. The segments are covered with dorsal plates.

The most available keys to the Myriapods are found in Pratt's *Manual of the Common Invertebrate Animals*. Other references are listed in the chapter bibliography.

BIBLIOGRAPHY

Myriapoda

Bollman, C. H., *The Myriapoda of North America.* U. S. Nat. Mus. Bull. 46, 1893.

Chamberlin, R. V., "The Chilopoda of California," *Pomona Jour. of Ent.*, Vol. 4, 1912.

——, *The Geophiloidea of the Southeastern States.* Bull. Mus. Comp. Zoöl., Vol. 54, 1912.

——, *The North American Chilopoda and Diplopoda.* Ann. Ent. Soc. Am., Vol. 5, 1912.

——, *The Millipedes of Central America.* Proc. U. S. Nat. Mus., Vol. 60, 1922.

Kenyon, F. C., *The Morphology and Classification of the Pauropoda with Notes on the Morphology of the Diplopoda.* Tufts College Studies No. 4, 1895.

Packard, A. S., *A Revision of the Lysiopetalidae.* Proc. Am. Phil. Soc., Vol. 21, 1900.

Pocock, R. I., "Centipedes," in 11th edition of *Encyclopedia Brittanica*, 1910.

——, "Millipedes," in 11th edition of *Encyclopedia Brittanica*, 1911.

Viosca, Percy, Jr., "Perambulating Millipedes," *Science*, Vol. LXI, 1925, No. 1566.

Wood, H. C., Jr., *The Myriapoda of North America.* Trans. Am. Phil. Soc., Vol. 13, 1865.

CHAPTER XIII

ARTHROPODS: THE SPIDERS AND THEIR RELATIVES

The Class *Arachnida* includes the spiders, mites, ticks, harvestmen or daddy-long-legs, scorpions, and horseshoe crabs. The group is characterized by: (1) four pairs of legs, although the young of some have only three pairs, and occasionally even adults (certain ticks) have only two pairs—the latter are mostly parasitic, which accounts for a modification of the usual number; (2) breathing effected by means of gills, tracheae, book lungs, or by blood gills; (3) eyes simple (except in *Xiphosura*), usually eight in number; (4) no antennae; (5) many forms with chelicerae or poison claws (jaws). Of these the spiders are the most conspicuous.

The Spiders

The universal fear of spiders is difficult to explain; and it has resulted in the development of numerous superstitions about spiders, most of which are entirely fallacious. It is commonly supposed that the great majority of spiders are poisonous and that they are courageous and aggressive enemies of man. However, there is little evidence to show that spiders, as a whole, are dangerous; and there is considerable evidence to prove beyond doubt that they are really cowardly creatures. The fear of spiders dates back to early times. In Italy the bite of the tarantula was supposed to cause a "mania" for which the only cure was to dance until exhausted. The exercise caused profuse perspiring which removed much of the poison. Certain forms of music were also regarded as helpful in the treatment of "tarantism," as the effect of the bite was called. Many musical compositions, to which the name "tarantella" was attached, were written primarily to stimulate the dancing. The Italian tarantula is a lycosid spider and not a true tarantula.

That spiders secrete a poison cannot be denied. Anyone watching an insect that has been bitten has seen the deadly effects of the poison injected by the jaws of the spider. But the amount of poison necessary to kill an insect and the amount necessary to

cause the death of a human being are vastly different quantities.

Most investigators insist that the average spider cannot pierce the flesh on the palm of the hand, and all of them testify to the apparent unwillingness of spiders to bite at all. Those which can and do bite do so only when captured, compressed or irritated, and the effects are rarely injurious.

In many parts of the world, tarantulas (*Aviculariidae*) are considered deadly poisonous, and there is no doubt that some of these spiders possess considerable virulence. Extracts made from the poison glands of the tarantula and injected into the bodies of sparrows and mice cause almost immediate death. Few cases of human deaths resulting from tarantula bites are on record, however, and in these there is some reason to believe that the real mortal cause was secondary infection. There is some indication, too, that there is a racial susceptibility to tarantula poison, and there is, of course, the question of individual sensitivity. Just as one person may eat strawberries and find them healthful while another person develops the well-known "strawberry rash," so may there be a supersensitiveness to spider poisons in some people. Tarantulas are mostly southern or tropical, the several American species in the United States being confined chiefly to the Southwest and Far West. They are rather common in California.

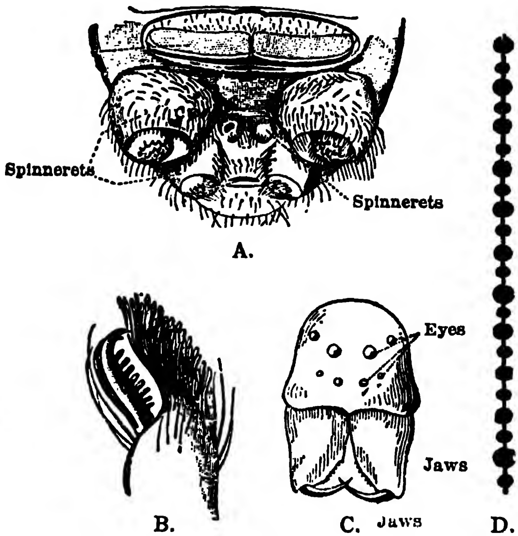


FIG. 53. Details of a spider. A. Abdomen; B. Foot; C. Head; D. Part of the web. From Hegner, *College Zoology*.

Tarantulas are frequently imported on bananas, but most of the hairy spiders that are ordinarily seen are not tarantulas at all. The commonest banana spider is probably *Heteropoda venatoria*.

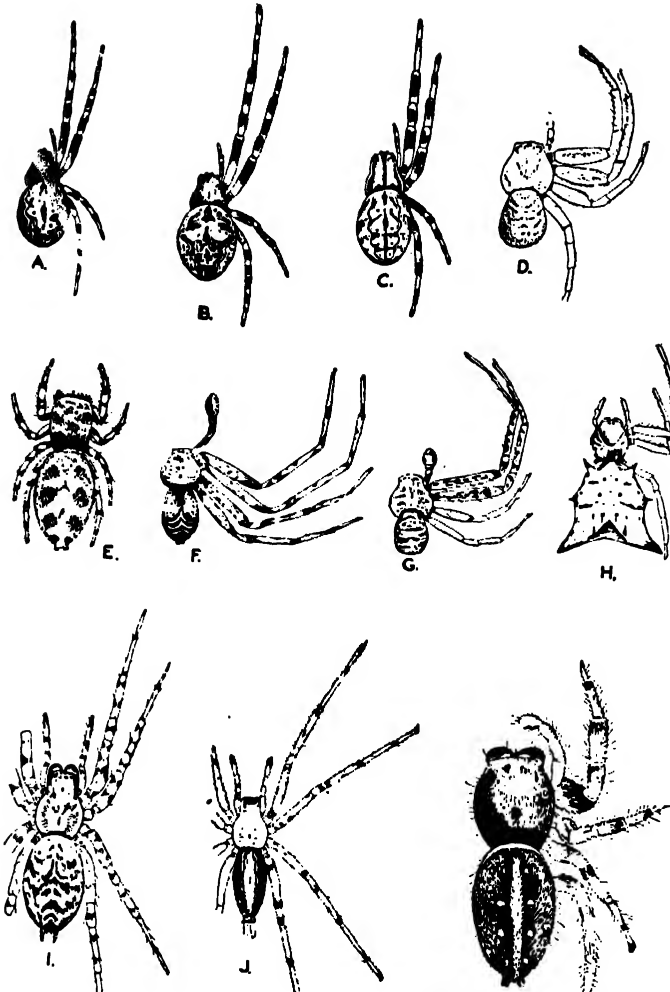


Plate VII. Some common spiders. A. *Epeira patagiata* (*Argiopidae*); B. *Epeira sclopetaria* (*Argiopidae*); C. *Epeira strix* (*Argiopidae*); D. *Xysticus nervosus* (*Thomisidae*); E. *Dendryphantes aestivalis* (*Attidae*); F. *Philodromos vulgaris*, male (*Thomisidae*); G. *Xysticus nervosus*, male (*Thomisidae*); H. *Acrosoma spinea* (*Argiopidae*); I. *Tegenaria medicinalis* (*Agalenidae*); J. *Agalena naevia* (*Agalenidae*); K. *Phidippus multiformis* (*Attidae*). After Emerton, *Common Spiders*, courtesy Ginn and Co.

The fear of tarantulas has resulted in the [illegible] *tarantula to all large spiders* [illegible]

The spiders of the genus *Latrodectus* (family T[illegible]) [illegible] ever, are well known to be virulent and many of them are [illegible] capable of inflicting serious poison wounds in humans. The commonest representative of this group is the "black widow," a name erroneously applied to several members of the group throughout the United States. The eastern form of *L. mactans* is a coal-black spider which frequents outhouses, barns, and stony places where it constructs a large funnel-shaped cobweb. The body of the female is almost half an inch long and has yellow or red spots, or both, along the mid-dorsal line of the abdomen. There is usually an hour-glass marking distinctly visible on the underside of the abdomen. The male is much smaller, and in addition to the dorsal spots of red or yellow, it has four pairs of yellow stripes along the sides of the abdomen. The western form is somewhat similar and is equally venomous. Many deaths have recently been attributed to the western black widow spider.

The only other virulent spider of any importance is the jumping spider, *Phidippus audax* (*tripunctatus*) (family *Attidae*), which lives under sticks and stones on the ground. It is usually black with three white spots on the upper side of the abdomen. The females are about a half inch in length, and the male is, as usual, much smaller. This species is supposed to cause a painful wound.

As to the other spiders, there is little need for concern. Most of them are harmless and wary. In addition to the part spiders have played in medical literature, there are many literary and historical treatises which discuss their habits. Robert Bruce is supposed to have escaped his pursuers because a spider web that covered the entrance to the cave in which he was hiding was unbroken when his enemies were searching for him. He is also supposed to have been stimulated to his final and successful attempt to regain his power by watching a spider's persistent attempts to attach a corner of its web.

On the whole, spiders are remarkably interesting creatures which exhibit striking and interesting characters and habits. One is well rewarded for his study of them.

There are many kinds of spiders. Each kind has its own set of habits and its own preferred habitat. Each also has its own manner of making its web.

Before discussing the various spider groups, let us consider the general characters by which spiders are distinguished from other animal groups (Fig. 53). Spiders have two main body regions, a cephalothorax or prosoma, and an abdomen or opisthosoma. As a rule, the abdomen is larger than the cephalothorax in females and in most males; but, unlike the other Arthropods, the abdomen is unsegmented. There are eight legs, all attached to the thoracic region of the cephalothorax. The spiders of the world display a variable number of eyes, some of them lacking two, four, or six of the usual number. However, most of our native spiders have eight simple eyes located on the forepart of the cephalothorax

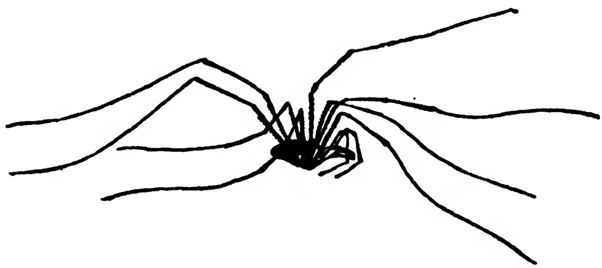


FIG. 54. A harvestman or daddy-long-legs (*Phalangium opillo*). From Hegner, *College Zoology*.

and so distributed over its curved surface that they are directed in several ways so as to increase the scope of vision. Some native six-eyed spiders are mentioned later on. The arrangement of the eyes, or eye pattern, is of value in determining species, since the pattern for each species is characteristic. The cephalothorax and abdomen are joined by a slender waist or pedicle which is hidden in most spiders by the overhanging abdomen. In those spiders resembling ants, the pedicle is rather prominent. The abdomen is a more or less elongated, cylindrical sac in which there is considerable diversity of form and color pattern. On the underside of the abdomen are the reproductive orifices. On the male, the small median opening of the sperm ducts or vasa deferentia is usually invisible. On the female, however, the opening of the oviducts is larger; and it is surrounded by a variable structure known as the epigynum. In its simplest form the epigynum is merely a transverse aperture; but it is generally an opercular plaque which is rather prominent, and in which the spermathecal openings are discernible. The diversity of form in the epigynum makes it an

invaluable structure in the determination of species. The epigynum is only present on mature females. The underside of the cephalothorax is called the sternum.

On the abdomen, at some distance from its tip, are located the spinning organs, or spinnerets, usually six in number. Immediately in front of the spinnerets on some spiders (the cribellate spiders) there is a plate punctured by many small outlets. This is the cribellum, an additional spinning organ. The cribellum is usually separated by a median, convex keel; and the number of perforations which serve as spinning tubes may total almost 10,000 in certain species. The individual spinneret is a finger-like organ with a number of microscopic tubes at the end, through which the thread is drawn out. The thread is composed of a great number of minute threads which pass from the body through separate tubes and unite into one before they have time to dry. When not in use, the spinnerets are folded together so that the smaller, inner pair are concealed. In front of the spinnerets there is an opening of the tracheae or air tubes. On the anterior ventral end of the abdomen there is also a transverse skin fold at the ends of which are other openings of the respiratory system. There are no antennae on spiders, but the chelicerae (mandibles or chelae) are prominent. These are the weapons of defense and offense. The chelicerae are homologous to the second antennae of crustaceans; and they are composed of two segments, the basal one being the tige or paturon. The distal segment is called the fang, unguis, or crochet. Through the hollow, hypodermic-needle-like fangs, the poison is injected into the victims. The second pair of appendages is known as the pedipalpi. These are leg-like structures which are, as a rule, very prominent on mature males; and they are used in courtship, while the coxae of the pedipalpi are used as crushing organs. The food is crushed just below the mouth. The pedipalpi are quite variable, and in many species they are greatly modified and colored, especially on males.

The legs, always eight in number, are seven-jointed, consisting of the articulating segment, the coxa, followed by the trochanter, femur, patella, tibia, metatarsus, and tarsus. The tarsus bears claws, the number of which is dependent upon the kind of spider. The legs are also variable in length, and the length modifications in different species cause them to walk in different ways. Up to the final molt, spiders are able to practice autotomy or self-mutilation,

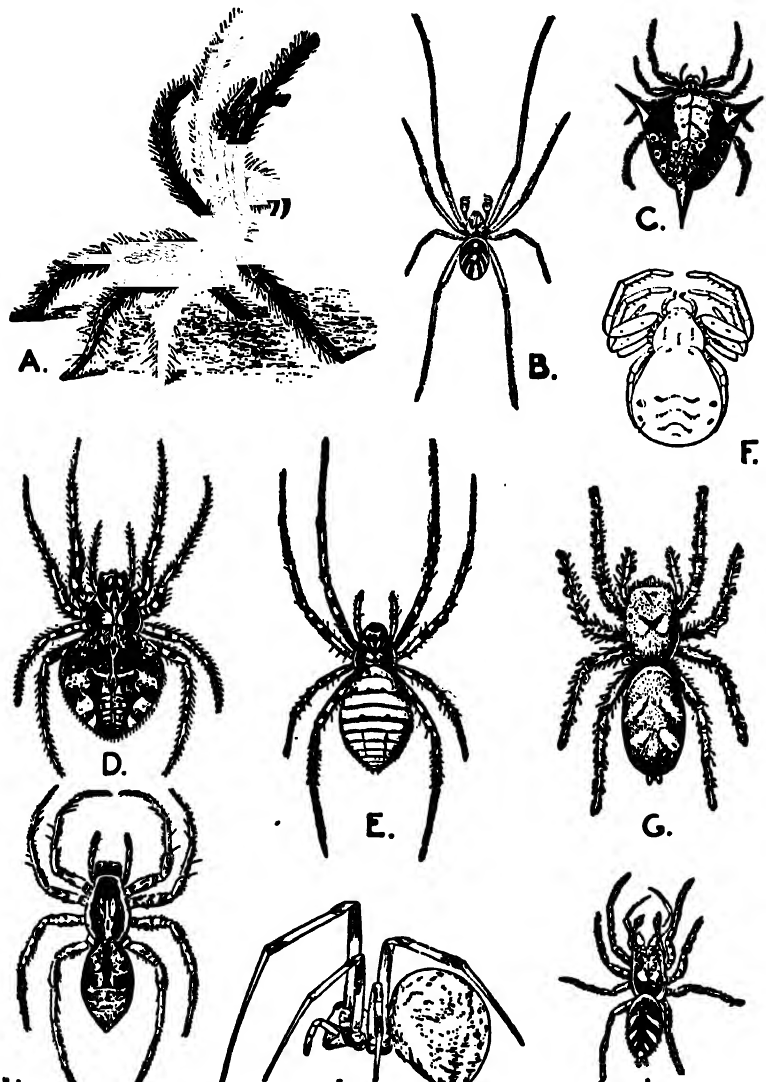


PLATE VIII. Some common spiders. A. A tarantula, *Chilobrachys stridulans* (*Aviculariidae*); B. *Latrodectus mactans* (*Theridiidae*); C. *Trithena tricuspidata* (*Theridiidae*); D. *Epeira angulata* (*Argiopidae*); E. *Argiope aurelia* (*Argiopidae*); F. *Thomisus sp.* (*Thomisidae*); G. *Attus sp.* (*Attidae*); H. *Lycosa fabrilis* (*Lycosidae*); I. *Theridion tepidariorum* (*Theridiidae*); J. *Salticus scenicus* (*Attidae*). After Watburton from Hegner, *Invertebrate Zoology*.

and they can regenerate lost limbs. When a spider is caught by a leg, it can shed the leg automatically in order to escape; and, as has been indicated, a new leg will be regenerated in place of the lost one, if the spider is not mature. The body of the spider is usually quite hairy or setiferous. The hairs may be protective or sensory. On the metatarsi of all cribellate spiders there is a group of hairs which constitute a comb (calamistrum), which is used in combing the threads from the cribellum. This is apparently of value in manipulating the thread in web-making. On the *Theridiidae* there is also a tarsal comb which is sometimes used to fling the thread over a struggling victim which has been caught in the web. The orb weaver uses its hind leg in guiding the thread. The claws on the tarsi are variable and valuable in classification.

As in other Arthropods, the body of the spider is covered with a lifeless, chemically complex, skeleton of chitin. The spider must shed this skin from time to time in order to allow for growth. All spiders lay eggs which are encased in a cocoon. Sometimes the cocoon is carried about with the mother either on the tip of her abdomen, or underneath the body, while in many species the cocoon is tucked away in some convenient place. As described later, some spiders make nursery webs in which the young are born. On hot, sunny days, ground-nesting species may be seen at the entrance of their burrows incubating their eggs by holding their cocoons at the openings where they are exposed to the sun. The mother turns the cocoon over and over so that all sides may get warm. Spiders do not undergo a metamorphosis; and upon hatching, the young spiders resemble their parents. As a rule they usually cling to the body of the mother; and an old spider may sometimes be seen with hundreds of little ones scattered all over her body. Species are known in which the young spiders devour the parent.

The web is a complex structure, as variable as spiders themselves. It is composed of almost microscopic thread-like strands made from a liquid that exudes through the numerous tubes on the spinnerets. Upon coming into contact with the air, the liquid hardens into the strongest and most delicate thread known. The thread can be manipulated and spun in the same manner as silk. It is much softer, stronger, and more delicate than silk, however. While it is still used for determining the foci of lenses on optical instruments and microscopes, it is too difficult to obtain in sufficient quantities for other commercial purposes. The uses of the

thread are many and diverse. One of the most interesting of its uses is its adaptation for aerial transportation. The "ballooning spiders" are those which climb upon fence posts, or out to the end of a branch where there is a current of air. When located, the spider turns its head toward the breeze and emits a droplet of liquid which is drawn into a thread by the current of air. When the thread is sufficiently long and the wind resistance against it is greater than the weight of the spider, the creature is lifted up and goes ballooning through the air, sometimes for hundreds of miles. Darwin reported the appearance of ballooning spiders on the deck of the *Beagle*, sixty miles from land.

Sometimes the smaller species may run quickly up a stem and rise immediately into the air as though they are winged. The familiar strands of gossamer which cling to one's face in summer and which may be seen floating through the air on sunny days are really the discarded balloons of some little spiders which have felt the urge of the wanderlust; and, being unable to migrate over land because of the distance and dangers, they have taken to the air. These migrations may be observed in late summer and early fall. If one of these spiders is placed on a stick and surrounded by water so that it cannot escape, its activity may be observed. At first it will run up and down the stick and investigate every possible means of escape. If the observer uses a fan and gently forces a draft of air on the stick, the spider will quickly run to the top, poise there, and proceed immediately to spin a thread which will serve either as a balloon by which it will be lifted into the air or the sticky thread will become attached to a nearby object and serve as a bridge over which the prisoner may escape.

Many spiders such as the wolf spiders (*Lycosidae*), which do not usually construct permanent homes, use the thread for lining their nests and for making cocoons. The jumping spiders (*Salticidae* or *Attidae*) do not as a rule establish permanent webs. They migrate from place to place, seeking a desirable spot for their predatory activities. They forage in sunny places. They are frequently seen on the bark of trees, windows, and on unpainted boards where they remain inactive until a fly or other food animal comes within range. When the unsuspecting victim gets close enough, the spider jumps on it and sinks its jaws into it. Not infrequently the spider anchors itself with a thread before leaping so that it will not fall, in much the same manner as a tinsmith ties a rope around his

waist when he is repairing a steep sloping roof. Usually the color of the spider matches the area in which it hunts, and it is therefore invisible to its victims.

The thread is frequently used by spiders for lowering themselves from heights and for raising themselves as well, in much the same manner as measuring worms do. Certain of the *Argiopidae* which build their webs close to the ground frequently have rather heavy nocturnal moths hit their webs and get caught momentarily; that is, until the struggles of the moth combined with its weight cause the web to give way, and the moth drops to the ground. Undaunted the spider descends on its thread and proceeds to swathe the moth in a silken shroud. The spider ascends, reinforces its web, and slowly raises the moth from the ground. Working tirelessly and deliberately, the thread is arranged time and again; and each time the moth is lifted higher and higher until it is finally secured in the center of the web. Such feats of engineering skill may be observed by any persistent and interested student. Many web builders tie up large and obstreperous victims which get caught in their nets and which might tear the net apart in their struggles to extricate themselves. The trapdoor spider of western United States uses its silk to cover the inside of its cylindrical burrow, which is made in the ground and in which the spider hides with the round, mud-covered, hinged lid held partly open. When the spider is disturbed, the lid is allowed to drop suddenly, closing the burrow. The top of the lid or trap is covered with mud and débris like the surrounding surface of the ground; and when closed, the burrows are hard to find.

The European diving spider, *Dolomedes*, goes beneath the surface of the water in its search for food. Sometimes it constructs a small, bell-shaped tent, spun among the branches of an aquatic plant. The bell is filled with air which is carried down by the spider and introduced into the bell. The air displaces the water in the inverted bell; and the spider then has a dry, cozy, silken room in which to rest. The hairy body of the spider has air spaces between the hairs so that when the spider submerges, it is covered with a silvery film of air. Frequent trips are made to the surface for fresh air to replenish the supply in the chamber. In the chamber the eggs are laid and the young are born. The air keeps out the water, and the opening of the chamber is covered with a pane of water in which swimming forms may be found. The spider

seizes these as they swim by. A number of spiders extend their foraging expeditions onto the surfaces of ponds and slow-moving streams where they reap a harvest of insects that have fallen into the water. The spider uses the surface film for support just as water striders do. Several American species of *Dolomedes* descend into the water to capture food. There is no evidence that any of these construct submarine nests, however.

The courtship of spiders. In the wooing activities of male spiders we may see some interesting analogies to similar processes in humans. In the webless spiders such as the runners and jumpers the male usually has elaborate palpi which he displays prominently, waving them back and forth in semaphore fashion before the female of his choice. Sometimes the male disports himself in the manner of a cocky young swain, strutting back and forth before the female. At other times he sways and dances toward the female, who in a few cases rather shyly backs away. Occasionally she also becomes excited and joins in the dance. When this takes place, the male's suit is successful. In certain species of one family, the *Pisauridae*, the male catches a fly and carefully swathes it in silk and then presents it to the female of his choice.

In some of the house spiders the male drums upon the web of the female with his palpi. She immediately comes to the entrance of her hiding place; and the male advances with gusto, swaying, dancing, and walking on his hinder legs. He finally, with a quivering of his body, touches the female; and she immediately falls into a cataleptic trance. The male then seizes her by a leg and drags her about, finally mating with her. She apparently does not awaken until the activity has been completed. In another of these spiders the male approaches the female, constantly vibrating the threads of the web and dancing in circles about her retreat. When the female is in the humor, she answers the male's signal by pulling at the threads also. In the orb weaver the male ascends the web of the female and finally seizes the communicating thread which leads to her retreat. The two signal to each other by plucking at the threads as though playing a harp.

In most species courtship is a rather dangerous procedure for the males, which are usually much smaller than the females. If the suit is unsuccessful, the female rushes out and attacks the male as though he were an imprisoned fly, carries him into her

nest, and devours him. Anyone can observe the mating habits of spiders, and the observer will be well rewarded for his efforts.

Breathing. It has been suggested that many spiders breathe by means of tracheal systems. The *Arachnida* stand, phylogenetically, between the *Crustacea* and the *Insecta*. Consequently the respiratory processes are, characteristically, modifications of both of these groups.

Spiders, being terrestrial, have no gills; but in many species there are gill-like structures which consist of from fifteen to twenty breathing plates, resembling the leaves in a book. These are the book lungs or lung books which lie in a hollow space at the margins of the anterior end of the abdomen. The lung books are connected with the exterior by means of a small pore already referred to.

In the most primitive groups, only the lung books are present. In most spiders, however, there are also tracheal tubes, the branches of which ramify throughout the body in a way similar to the system found in insects. The tracheae open to the outside through the single median spiracle or breathing pore, visible on the underside of the abdomen. A few spiders, however, have a pair of spiracles.

Classification. The spiders belong to the Phylum ARTHROPODA, Class ARACHNIDA. The word *Arachnida* probably is an application of the name of the Greek *arachne*, meaning "spider," and of the Greek *eidos*, meaning "shape," although some definitely connect it with Arachne, the spinning goddess.

In the Class *Arachnida* there are five common orders, several others being relatively unimportant here: (1) *Xiphosura*, the horseshoe crabs or king crabs; (2) *Scorpionidea*, the scorpions; (3) *Phalangidea*, the harvestmen or daddy-long-legs (Fig. 54); (4) *Acarina*, the mites and ticks; and (5) *Araneida*, the true spiders (Plates VII and VIII).

Of these the spiders are the most commonly seen and generally distributed. In the United States there are 12 prominent families as follows:

(1) *Aviculariidae*—the tarantulas and trapdoor spiders of the Southern and Southwestern states and the Far West. All of them are large, eight-eyed, hairy spiders with the chelicerae capable of being extended forward. A number of species in the family make burrows in the ground. In the trapdoor spiders, the burrow is closed with a lid. The bird spiders are tarantulas which roam about

at night in search of food. During the day they hide in ready-made retreats or in self-made burrows. There are others which lie in wait for their victims. One group of tarantulas, the *Diplurinae*, constructs funnel webs similar to those of the grass spider. All of our tarantulas and trapdoor spiders are confined to the Far South, Far West, and the Southwest sections in the United States.

(2) *Agelenidae*—including many household species and the makers of the flat, wide cobwebs, which have a tubular retreat in the rear of the center, found in the grass and in barns and cellars. These spiders have three claws, eight eyes, and are somewhat sedentary in their habits as a rule, although some of them are wanderers. They are often referred to as the funnel web builders.

(3) *Uloboridae*—small spiders possessing a cribellum and calamistrum. The eyes are all dark colored which indicates diurnal habits. The lateral eyes are farther apart than the two pairs of median eyes. Length not more than 8 mm. Common in shady woods and low bushes and especially in lower branches of pines. Web small, circular in genus *Uloborus*, and triangular in *Hyptiotes*.

(4) *Theridiidae*—the builders of the loose and apparently irregular webs in the corners of rooms, in fences, in hollow places in rocks, and between the branches of low trees and bushes. Sometimes goldenrods and other low herbaceous plants have their entire floral clusters completely covered with the webs of the members of this family. The *Theridiidae* are known as the comb-footed spiders, which may be distinguished from all other three-clawed, eight-eyed spiders by the presence of a comb of strong, toothed, and curved setae, located on the tarsi of the fourth pair of legs. The comb is usually distinct and is used for throwing silk over entangled prey. In some of the *Theridiidae* there is a stridulating organ which is said to produce sounds used in courtship. The venomous *Latrodectus*, or black widow, belongs to this family; but most of them are harmless. The spiders of this family usually hang back downwards in their webs.

(5) *Linyphiidae*—sheet-web weavers. These are small spiders which live in shady woods where they lurk among the lower branches of plants and under the leaves. Sometimes they inhabit caves and cellars, while very small species live close to the ground among short grass and moss. Their delicate sheet webs are almost

invisible. The body is more elongate than in the *Theridiidae*, and the legs are stouter with more spines. The mandibles are large. Some members of the family are reported to possess stridulating organs on the chelicerae. All of them are three-clawed, eight-eyed, sedentary spiders which make webs of one or more sheets of silk. Several species make dome-shaped webs beneath which they live. There are two groups (subfamilies) in this family, the *Linyphiinae* and the *Erigoninae*; and since there are so many genera and species, it is difficult to differentiate among them. Many of them are aeronautical. While most of them are dull colored, a great number have distinct markings. Violent color contrasts are never present, however.

(6) *Argiopidae*—the orb weavers. These spiders build the spectacular orb webs with which most of us are familiar. The webs are frequently stretched across paths, streams, and doorways. Some species do not make webs at all. The family is a large one, including robust and slender species. Most of the common forms belong to the Genus *Aranea* (*Epeira* of some authors) which have rounded abdomens. In many cases the abdomen is decorated with spines and humps, giving the spider a grotesque appearance. Some of them are so constructed as to resemble buds, twigs, or spiny stems. In this family there are long, slender species with elongated thorax and abdomen which belong, mostly, to the genus *Tetragnatha*; and these have long, prominent mandibles and long legs. Many of the orb weavers are brightly colored. The habitats of the numerous members of this family are diverse.

(7) *Dictynidae*—the hackled band weavers. Cribellate spiders with a longitudinal median furrow on the cephalothorax. Anterior median eyes dark; lateral ones pearly white and very close together. The tarsi bear three claws and the spinnerets are all about the same length. The family contains four genera, only two of which are common.

Amaurobius is found in crevices of rock, on walls of rock, on cellar walls, and in old stumps. An irregular web surrounds the entrance of the retreat. There are several species of this genus, but *Amaurobius ferox* is probably the most common. It is a small spider found in cellars, under floors, and in outbuildings.

Dictyna is also a commonly found genus, the members of which spin irregular webs on the branches and bark of trees and frequently on the outside of window sashes. These are all small, dark-colored

spiders not more than a third of an inch in length and usually smaller.

(8) *Thomisidae*—the crab spiders. These are generally flat, short, and widened behind, and they run sidewise as do crabs, hence their common name. The first two pairs of legs are usually longer than the others, and all legs extend sidewise from the thorax and not forward and backward as in most other spiders. The crab spiders are frequently found resting in flowers where their bright colors make them inconspicuous. The males are often brilliantly colored with red, green, or yellow. Most females are white or yellow although in some species the females are as gaudy as the males. The colors of the males and young females usually occur in bands. The spiders are sedentary in their habits, patiently waiting for the insects which visit the flowers.

(9) *Lycosidae*—the wolf spiders. These are wandering, long-legged, ground-colored spiders which are the most frequently seen of all common spiders. They roam about on the ground near the water, as a rule, often running over the surface of the water in search of victims which they pursue with surprising speed.

Many of the largest native spiders belong to this family, and the females carry their rounded cocoons about with them, attached to their spinnerets. After hatching from the eggs, the young ride about on the body of their mother for a time. The eyes have a peculiar arrangement which distinguishes them, occurring in three rows of four, two, and two. The abdomen is usually about as long and as wide as the cephalothorax.

Most of the activities of the lycosids are carried on at night, and they rest in crevices and under stones and logs during the day. While the lycosids are chiefly nomadic and have no special abodes, they utilize cavities for temporary shelter and in late fall the young spin their webs on the tops of plants and fences. In most species the immature young hibernate during the winter months and mature the next summer. A few of the lycosids make burrows.

(10) *Attidae* or *Salticidae*—the jumping spiders. These are usually short, stout spiders with a wide cephalothorax and short legs. They can jump in any direction and they do not spin webs, except for breeding and hibernating purposes. They live in open places such as the tops of plants and on the surfaces of buildings, rocks, and barks of trees. Some of them are brightly colored, and

most of them have a coloration which renders them inconspicuous. The front legs are usually the thickest, especially in males. The feet have only two claws, and the eyes occur in three rows; but those of the third row are placed far back on the head. The eyes of the front row are much larger than the others. In many of the jumping spiders there are such differences between the males and the females that they are apt to be considered different species.

(11) *Drassidae.* The *Drassidae*, like the *Lycosidae*, are fairly large spiders; and they are usually ground spiders, although there are two or three genera which are rather common on bushes. They are most frequently seen running among dead leaves or short grass. Their nests are usually bags or flattened tubes, and they may be found among the dead leaves or on stones. The flattened, roundish cocoons about the size of a penny which are seen on awnings and on the undersides of stones are those of members of this family. None of the species makes cobwebs for catching insects. In form the *Drassidae* are generally several times as long as they are wide. They differ from the lycosids by being a little flattened on the back. The first two pairs of legs are directed forwards while the second and third pairs extend backwards. The feet have two claws with a brush of flattened hairs on each foot. Their bodies are velvety in appearance due to a body covering of very short hairs and spines. The eight eyes are all about the same size, and they are arranged in two rows which are close together. The mandibles are very large, and together they are as wide as the head. Most members of the family are dull colored, gray, brown, and black with few or no markings, although there are several species which are brightly marked.

(12) *Pisauridae.* On the whole, these are rather large hunting spiders which do not make permanent nests. The female spins a large, round cocoon which she carries beneath her body until just about time for the young to hatch, when she constructs a nursery by fastening the cocoon among the leaves at the top of a herbaceous plant or on the end of a branch of a tree or shrub. After securing the cocoon, a number of surrounding leaves are bound together by a loosely woven web. The mother spider remains outside the web, guarding the young against enemies. The commonest pisaurid spiders belong to the Genus *Dolomedes* which includes the diving spiders. Other members of the genus are generally found near water. The pisaurids are long-legged run-

ners with bodies mostly gray or black with lighter markings. Many of them have gray bands on the legs. They are all eight-eyed spiders with the eyes quite variable in size and arrangement. They are frequently mistaken for wolf spiders (*Lycosidae*); but they are larger, as a rule.

There are numerous other families of spiders, most of which are identified by size, pedipalpi, epigynum, calamistrum, eyes, and chelicerae. The list is too long for inclusion here since the characters are diverse. As with the specific identification of most large animal groups, the student is referred to the bibliography appended to the chapter.

Considered as a whole, spiders are so variable as to warrant extensive discussion; and several interesting books have been written about them. The student is referred to these for further study.

Spiders make excellent laboratory specimens. They may be captured in bottles and kept in jars where their activities can be readily observed. They can live for months without food, although they consume considerable water.

Specimens for the permanent collection should be preserved in alcohol, to which small quantities of glacial acetic acid and formaldehyde have been added. The liquid should be quite warm when the specimen is placed in it, to preserve the color.

The habitats of some common spiders. A brief résumé of the habitats of some common spiders is here appended, but the interested student must continue his studies in the references listed at the end of this chapter.

Spiders are to be found in all sorts of places; and while they vary their habitats somewhat, there is, nevertheless, a rather definite selectivity among them.

A knowledge of their preferences for home building and foraging helps considerably in their determination. The light webs in the corners of rooms are chiefly those of *Theridium tepidarorium, Steadota borealis,* and *S. triangulosa.* In cellars the thin webs about the stairs and shelves are those of the long-legged *Pholcus phalangioides,* or of *Liniphyia nebulosa,* or *L. minuta.* The thick, flat webs in corners and between the beams are the work of *Tegenaria derhami.* On the outside of wooden buildings the two jumping spiders, *Epiblemum senecium,* a small gray spider with the color of weather-beaten wood, and *Marptusa familiaris* are the

species most frequently found. In and about houses are to be found several round-web or orb-web makers also. *Aranea* (*Epeira*) *sclopetaria*, *A. patagiata*, and *A. strix* are brownish spiders which hide in the cracks during the day and make round webs at night in porches, barns, and wooden bridges. In the northern states *A. cinerea* has the same habits.

The small, flat webs which collect dust and become conspicuous on the walls of houses, in corners of windows, and under the edges of shingles, are made by several species of *Dictyna*. These are small spiders, not more than a sixth of an inch long, and sometimes brightly colored. They belong to the family *Dictynidae*.

In Southern states one of the most common house spiders is *Filistata hibernalis* (*Filistatidae*). Its web often makes a dusty spot almost a foot in diameter.

The habitat of many species is under stones and sticks on the ground. Among the kinds to be found in such situations are: *Steadota borealis; S. marmorata; S. guttata; Asagena americana;* and *Latrodectes mactans*, the poisonous black widow in the family *Theridiidae*. The large jumping spiders, *Phidippus mystaceus, P. audax*, and *P. tripunctatus* (*Attidae*) make large white silken nests under stones on the ground. Some spiders merely hide under the stones where they may be taken during the day. Among these are *Drassus saccatus, Gnaphosa conspersa* (*Drassidae*), and *Prosthesima atra*. The wolf spiders, *Lycosanidicola, L. communis, L. pratensis, L. polita*, and *L. cinerea* also hide under stones and logs (*Lycosidae*).

The crab spiders of the genus *Xysticus* may sometimes be found under stones also, but they usually live on or under the bark several feet above the ground.

In summer plants are excellent collecting places for the student of spiders. The Lycosids run among the short grasses. The smaller species of *Liniphyia* and *Erigone* make their flat webs close to the ground among low plants. On the rocks a few feet above the ground are to be found the webs of *Liniphyia marginata* (*Liniphyiidae*), *L. communis, L. coccinea*, and *L. phrygiana*. The members of the genus *Theridium* live in irregular webs constructed between leaves and on the ends of twigs and herbaceous plants. Their webs are distinctly visible when the dew is upon them. The flat web, or funnel web, of *Agalena naevia* is found on the grass and hedges. A few of the jumping spiders have silk nests

among the leaves, while the *Misumena*, a genus of crab spiders, lives among the flowers where it waits for insects to alight within reach. Some members of the genus *Dictyna* are found on the ends of grasses.

The round-web builders appear in succession during the summer months. These belong to the genus *Aranea* (*Epeira-Argiopidae*). *E. trivittata* builds its round web on all kinds of bushes and grasses. It is followed by *E. insularis* and *E. trifolium*. In the bushes and trees live *Epeira angulata, E. sylvatica,* and *E. nordmani*. In the open spaces in woods where low bushes grow are several common species such as *Cyclosa comica* (*Argiopidae*), *Acrosoma spinea* (*Argiopidae*), and *Uloborus plumipes* (*Uloboridae*). The small *Hyptiotes cavatus* (*Uloboridae*) lives among the lower dead branches of pine trees where it perches on the ends of twigs, almost exactly matching the color of its perch.

In the marshes and along streams and ditches, members of the genus *Tetragnatha* (*Argiopidae*) abound. These are the elongated, long-legged spiders mentioned before. They may be collected in great numbers by sweeping the bushes and grasses with an insect net. On the tall grasses in the open marsh, the oblique and horizontal webs of *Epeira* (*Aranea*) *placida* and *E.* (*Aranea*) *gibberosa* appear. The two orb weavers, *Argiope riparia* and *Argiope transversa,* also abound in the marshes where they leave their brownish cocoons attached to the grasses during the winter months.

The serious collector who is intent upon obtaining all of the species in a given locality will also find an abundance of spiders in the mosses and dead leaves on the woodland floor. This is an excellent place to collect hibernating species.

The Harvestmen

Order Phalangida—the harvestmen or daddy-long-legs. Harvestmen (Fig. 54) are commonly found in most sections of the United States. Unlike the spiders, the body is composed of what appears to be but one region. However, there is a cephalothorax in addition to the abdomen, although there is no constriction between the two. The abdomen consists of nine more or less distinct segments. The genital organs are situated between the margins of the cephalothorax and abdomen. They consist of an ovipositor in the female and a penial structure in the male. There are only two eyes located on a prominent tubercle on the anterior

margin of the cephalothorax. On the sides of the cephalothorax, just opposite the attachments of the first pair of legs, are two pores which lead to scent glands. The respiratory system consists of tubular tracheae which open through spiracles on the underside of the abdomen. In some species there are also accessory spiracles on the legs. The four pairs of legs are very long and slender; and many a daddy-long-legs has lost a leg in its attempts to free itself from the fingers of some farmer lad who held it suspended by one leg as he begged, "Daddy-long-legs tell me where the cows are." Like the spiders, the harvestmen can practice autotomy.

Harvestmen lay eggs under stones or in the crevices of bark. When first hatched, the young are white with coal-black eyes. Harvestmen have jaw-like chelicerae, and they feed upon plant lice and other small insects. Their defenses consist chiefly of their ability to run rapidly and to traverse rough areas over which their pursuers cannot make much headway. There is some protection rendered by the scent glands and in having the body raised above the substratum. As far as is known, the harvestmen have no silk glands, and they construct no shelters. There are six families of harvestmen in the United States; viz., *Cosmetidae*, confined to the southern and warmer sections; *Phalangididae* with a wide distribution; *Phalangiidae* with generally distributed species; *Ischyropsalidae* which is confined to the Midwest from Colorado to New Mexico; *Nemastomatidae* with species in Alaska, Washington, and one cave-dwelling species in eastern United States; *Trogulidae*, confined to the Pacific slope.

The Mites and Ticks

Order Acarina—the mites and ticks. This order of arachnids is composed of numerous small forms, most of which are parasitic on both plants and animals. Some species are found in the water, where they seek fishes, mollusks, and other aquatic forms upon which to live. Mites infest beetles, grasshoppers, and a host of other insects; and one southern form known as *bête rouge*, or red bug, causes considerable irritation in humans by burrowing beneath the skin. Nearly all grasshoppers have mites under their wings. The harvest mites and itch mites are common irritating parasites on humans. Birds, bats, and other mammals are frequently infested with mites. Mites appear to have but one body

region because the cephalothorax and abdomen are broadly attached. The division of the body regions is difficult to see in many species. The abdomen is unsegmented although the last two thoracic segments are considered as being a part of the abdomen, and the third and fourth pairs of legs are attached to these segments. Most larvae have only three pairs of legs, but like all other arachnids the adults have four pairs. Most mites breathe through tubular tracheae, although a few lack a respiratory system and obtain oxygen through the body surface. There are both oviparous and viviparous species.

The ticks are more frequently seen than are the mites because they are usually larger. Ticks are parasitic on birds, mammals, reptiles, and amphibians. Toads are frequently seen with large wood ticks attached to their hind legs.

The mites and especially the ticks are noted for transmitting many diseases. The Texas cattle fever and the Rocky Mountain spotted fever are spread chiefly by ticks. Scabies, sheep scab, and numerous skin affections of birds, mammals, and human beings are transmitted or caused by several families of mites and ticks. Many galls on the leaves, stems, and roots of plants are produced by mites.

One interesting and little-known mite is the follicle mite, *Demodex folliculorum*, which is frequently present in the hair follicles and sweat glands of humans.

The group is a tremendous one, and its members are so diverse in habits as to imply considerable variation in species, especially in the parasitic ones. Mites may be studied under magnifiers, and they may be preserved in collections by placing them on glass slides and dissolving out the soft parts with a warm solution of potassium hydroxide. The skin can then be washed, dehydrated, and preserved in balsam.

The Scorpions

Order Scorpionidea—the scorpions. The scorpions are residents of southern and western sections, but they are generally well known because of their poisonous stings and defiant attitudes which have caused them to be pictured extensively in treatises on dangerous animals. However, while they possess a virulent poison, their stings seldom, if ever, result in the death of humans.

The most striking features of scorpions are the large size of

their pedipalpi, which terminate in a pair of pincer-like chelicerae; the flattened bodies; and the slender post abdomen. Unlike the spiders, the scorpions do not inject their poison through the chelicerae. Instead, the scorpion has a specialized stinging organ on the end of the abdomen. The sting has the appearance of an abdominal segment. When disturbed, the sting is raised considerably by the upward curling of the abdomen. With the sting the scorpion defends itself. The sting may be thrown forward over the back, as far as the head, or moved to sidewise positions by the swinging of the abdomen. The body of the scorpion is composed of three regions: the unsegmented cephalothorax; the pre-abdomen, which is composed of seven broad, flat segments; and the post abdomen, consisting of five rather slender segments. In addition to the pedipalpi and the sting, the scorpion has four pairs of walking legs attached to the cephalothorax. The legs all have tarsal claws. There is one pair of eyes near the median line on the anterior section of the cephalothorax, and on each side there is a group of from two to five other eyes, all of which are simple. On the lower side of the second abdominal segment, in mature specimens, there is a pair of comb-like organs called the pectines which are evidently sensory. Breathing is effected by means of four pairs of book lungs which open to the outside on the ventral surfaces of the third to sixth abdominal segments. The male has a longer post abdomen and broader pincers than the female.

Scorpions are viviparous and the young are born alive after having completed their development within the body of the mother. The young, after birth, cling to the body of their mother by means of their pincers. There are several species of American scorpions. All of them are nocturnal. Scorpions feed upon spiders and insects which they seize with their pincers and then sting to death.

BIBLIOGRAPHY

Spiders

Baerg, W. J., "The Effects of the Bite of Latrodectus mactans," *Jour. Parasit.*, Urbana, 1923, pp. 161–169.

Banks, N. A., *Mimicry in Spiders.* Proc. Ent. Soc. Wash., II, 1891, pp. 174–176.

Banks, N. A., "Synopsis of North American Phalangida," *Amer. Nat.*, Vol. 35, 1901.

——, *A Treatise on the Mites.* Proc. U. S. Nat. Mus., 1904.

——, *Spiders of Indiana.* Rep. Ind. Geol. and Nat. Res., 1906.

——, *Some Phases of Protective Resemblance in Our Spiders.* Proc. Ent. Soc. Wash., IX, 1908, pp. 2–9.

——, *Catalogue of the Nearctic Spiders.* U. S. Nat. Mus. Bull. 72, 1910.

——, *The Acarina or Mites.* Bur. Ent. Report 108, U. S. Dept. Agric., 1915.

Benton, J. R., "The Strength and Elasticity of Spiders' Thread," *Amer. Jour. Sci.*, XXIV, 1907, p. 75.

Bishop, S. C., *A Revision of the Pisauridae of the United States.* N. Y. Mus. Bull., Albany, 1924, No. 252, pp. 1–140.

——, *Singing Spiders.* N. Y. Mus. Bull., Albany, 1925, No. 160, pp. 65–67.

Borradaille, L. A., and Potts, F. A., *The Invertebrata.* Macmillan, 1932.

Brickner, R. M., "Observations on the Behavior of Spiders," *Ent. News*, XXXIV, 1923, pp. 78–84.

Chamberlin, R. V., *Revision of the North American Spiders of the Family Lycosidae.* Proc. Acad. Nat. Sci. Phila., 1908, pp. 157–318.

Comstock, J. H., *The Evolution of the Webs of Spiders.* Ann. Ent. Soc. America, V, 1912.

——, *The Spider Book.* Doubleday Page, 1912.

——, *The Habits of Spiders.* Toronto Ent. Soc., 45th Ann. Rept., 1915, pp. 49–50.

Ellis, R. A., *Spiderland.* Cassell and Co., 1912.

Emerton, J. H., *The Common Spiders of the United States.* Ginn, 1902.

——, "Four Burrowing Lycosids," *Psyche*, 1912, pp. 1–6.

——, "The Flights of Spiders in Autumn," *Ent. News*, XXX, 1919, pp. 165–168.

Ewing, H. E., *The Life and Behavior of the House Spider.* Proc. Iowa Acad. Sci., XXV, 1918, pp. 177–204.

——, *Manual of External Parasites.* C. C. Thomas, 1929.

Fabre, J. H., *Life of the Spider.* Dodd Mead, 1913.

Gudger, E. W., "Spiders as Fishermen and Hunters," *Nat. Hist. N. Y.*, XXV, 1925, pp. 261–275.

Hegner, R. W., *Invertebrate Zoölogy.* Macmillan, 1933.

Hents, N. M., *The Spiders of the United States.* Boston Soc. Nat. Hist., 1875.

Hutcheson, L., "Effects of Spider Bite on Man," *Ent. News*, XXVII, 1916, p. 464.

Johannsen, O. A., and Riley, W. A., *Handbook of Medical Entomology.* Comstock Pub. Co., 1915.

Kellogg, V., "Spider Poison," *Jour. Parasit.*, I, 1915, pp. 107–112.

Lester, A., *A Field Key to the Spider Families on Presque Isle, Lake Erie.* Univ. of Pittsburgh thesis, 1930.

Locket, G. H., *Observations on the Mating Habits of Some Web Spinning Spiders.* Proc. Zoöl. Soc., London, 1926, pp. 1125–1145.

——, "On the Mating Habits of Some Spiders of the Family Theridiidae," *Ann. and Mag. Nat. Hist.*, Series 9, Vol. XX, 1927, pp. 91–97.

Mallock, A., "The Eyes of Spiders," *Nature*, London, Vol. 113, 1924, pp. 45–48.

McCook, H. C., *American Spiders*, 3 vols., published by the author, 1889.

——, *American Spiders and Their Spinning Work.* Published by the author, Philadelphia, 1893.

McIndoo, N. E., *Notes on Some Arachnids from Ohio Valley Caves.* Biol. Bull., 1911, pp. 183–186.

Mitchell, C. A., "The Venom of Spiders," *Knowledge*, 1905, pp. 298–299, 317–318.

Moles, M. L., "Growth and Color Patterns in Spiders," *Jour. Ent. Soc.*, 1916, pp. 129–157.

Montgomery, J. H., *Descriptions of North American Araneae of the Families Lycosidae and Pisauridae.* Proc. Acad. Nat. Sci. Phila., 1904.

Montgomery, T. H., *Studies in the Habits of Spiders, Particularly Those of the Mating Period.* Proc. Acad. Nat. Sci. Phila., 1903, pp. 59–145.

——, "The Oviposition, Cocooning, and Hatching of an Aranead, Theridion tepidariorum," *Biol. Bull.*, XII, 1906, pp. 1–10.

——, *On the Spinnerets, Cribellum, Colulus, Tracheae, and Lung-books of Araneae.* Proc. Acad. Nat. Sci. Phila., XLI, 1909, pp. 299–320.

——, "The Significance of the Courtship and the Secondary Sexual Characters of Araneads," *Amer. Nat.*, XLIV, 1910, pp. 151–177.

Packard, A. S., "Change of Color and Protective Coloring in a Flower Spider, Misumena vatia," *Jour. N. Y. Ent. Soc.*, Vol. XIII, 1905, pp. 85–96.

Patterson, Alice J., *The Spinner Family.* A. C. McClurg Co., 1903.

Pearse, A. S., "The Influence of Different Color Environments on the Behavior of Certain Arthropods," *Jour. Anim. Behavior*, 1911, pp. 79–110.

Peckham, G. W., *Ant-like Spiders of the Family Attidae.* Occ. Pap. Nat. Hist. Soc. Wis., I, 1889, pp. 61–113.

——, *Protective Resemblances in Spiders.* Occ. Pap. Nat. Hist. Soc. Wis., Vol. I, 1889, pp. 61–113.

——, *The Sense of Sight in Spiders, with Some Observations on the Color Sense.* Trans. Wis. Acad. Sci., V, 1894, p. 10.

Peckham, G. W., and E. G., *Observation on the Sexual Selection of Spiders of the Family Attidae.* Cramer, Aikers, and Cramer, Milwaukee, 1889.

——, *Additional Observations on Sexual Selection of Spiders of the Family Attidae.* Occ. Pap. Wis. Nat. Hist. Soc., Vol. I, 1900, pp. 117–151.

——, *Revision of the Attidae of North America.* Trans. Wis. Acad. Sci., Vol. XVI, 1909, pp. 355–646.

Petrunkevitch, A., "The Sense of Sight in Spiders," *Jour. Ent. Zoöl.*, V, 1907, pp. 275–309.

——, "Courtship in Dysdera crotcata," *Biol. Bull.*, XIX, 1910, pp. 127–129.

——, *A Synoptic Index—Catalog of Spiders of North, Central, and South America.* N. Y. Bull. Amer. Mus. Nat. Hist., 1911, pp. 1–791.

——, *On Families of Spiders.* Amer. Acad. Sci. N. Y., XXIX, 1923, pp. 145–180.

Pickard-Cambridge, F., "On the Tarsal Comb in Spiders of the Family Theridiidae," *Jour. Micr. and Nat. Hist.*, 1890.

——, "Newly Discovered Stridulating Organs in the Genus Scytodes," *Ann. Mag. Nat. Hist.*, VI, 1895, pp. 371–373.

Pocock, R. I., "Notes on the Commensalism Subsisting between a Gregarious Spider Stegodyphus and the Moth, Bathracheda stegodyphobius," *Ent. Mo. Mag.*, 1903.

——, "Mimicry in Spiders," *Jour. Linn. Soc.*, XXX, 1909, pp. 256–270.

Porter, J. P., "The Habits, Instincts, and Mental Powers of Spiders of the Genera Argiopidae and Epeira," *Amer. Jour. Psychol.*, XVII, 1906, pp. 306–357.

Pratt, H. S., *A Manual of the Common Invertebrates.* A. C. McClurg Co., 1923.

Pritchett, A. H., "Observations on Hearing and Smell in Spiders," *Amer. Nat.*, XXXVIII, 1904, pp. 859–867.

Ran, P., "Some Life Notes on the Black Widow Spider, Latrodectus mactans," *Psyche*, XXXI, 1924, pp. 162–166.

Reese, A. M., "Venomous Spiders," *Science*, LIV, 1921, pp. 382–385.

Savory, T. H., "Evolution in Spiders," *Sci. Prog.*, XX, 1926, pp. 475–480.

——, *The Biology of Spiders.* Macmillan, 1928.

——, *The Arachnida.* Longmans Green, 1935.

Seeley, R. M., *Revision of the Spider Genus Tetragnatha.* N. Y. State Mus. Bull., Oct., 1928, No. 278, pp. 99–150.

Sheffer, T. H., *Cocooning Habits of Spiders.* Kan. Univ. Sci. Bull., Vol. VIII, No. 2, 1905.

Warburton, C., *Spiders.* Cambridge Univ. Press, 1912.

Watson, J. R., "Bite of Latrodectus mactans," *Science*, LV, 1922, p. 539.

Webster, J., "Protective Mimicry in Spiders," *Can. Entom.*, XXVI, 1894, pp. 36–37.

Weed, C. M., *A Descriptive Catalog of the Harvest Spiders (Phalangidae) of Ohio.* Proc. U. S. Nat. Mus., Vol. XVI, 1893.

Wood, F. D., "Autotomy in Arachnida," *Jour. Morph.*, XLII, 1926, pp. 143–195.

CHAPTER XIV

ARTHROPODS: THE INSECTS

The insects are, no doubt, the most abundant creatures on the face of the earth. They exist in every type of habitat known. They are to be found flying through the air; on and under water; on and in plants; on the surface of the ground and under it; on snow-capped mountains and desert sands; on and in the bodies of other animals; and in man's places of abode. They can also be found in the many types of nests made by them.

No other group of animals has so menaced man's welfare, and in no other has he found such valuable allies. Since man's advent on the earth he has successfully dominated the animal kingdom with the exception of the insects. These so-called lowly creatures have been his greatest competitors; and they have, at times, threatened his very existence. From time immemorial man has contended with insects which affect his person, his effects, and his sustenance. He has employed all of his chemical and mechanical genius in his efforts to save his crops, to protect his forests, and to check the spread of disease. Throughout the ages of his warfare against insects he has won but one complete victory and that was against the Mediterranean fruit fly recently in Florida.

There is some indication that insects were the principal contributors to the decline of ancient civilizations, including Grecian and Roman, through the spread of malaria.

Sleeping sickness, yellow fever, malaria, and other insect-transmitted diseases cause more deaths today in tropical countries than all other diseases combined. The successful completion of the Panama Canal and other important projects was made possible only after mosquitoes were controlled. The housefly, mosquitoes, bugs of several kinds, and numerous other insects are disseminators of fevers, skin infections, poisons, and tapeworms.

As will be seen later, beneficial plants of all kinds are seriously affected by destructive insects which include the cotton boll weevil, gypsy moth, Japanese beetle, European corn borer, army worm, cut worms, Rocky Mountain locusts, and thousands of

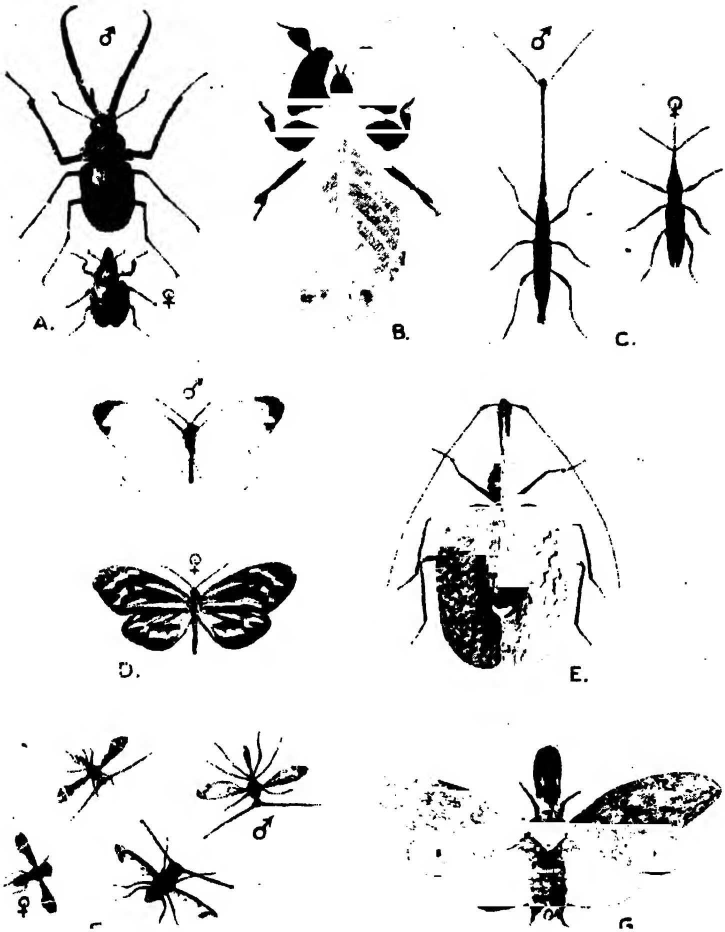


FIG. 55. Unique form and sexual differences in insects. A. South American beetle, male above and female below; B. East Indian walking-stick, illustrating protective mimicry; C. Snout beetles from New Zealand, male left and female right; D. South American butterfly, male above and female below; E. East Indian snout beetle exhibiting protective mimicry; F. Stalk-eyed flies from Africa, female lower left; G. Bug, the lantern fly from South America. From Brit. Mus. Nat. Hist.

others. The flower yard, vegetable garden, and orchard provide excellent sources for the study of a myriad of harmful, but interesting, insects. A number of these are discussed and figured later on. While it is true that there are thousands of objectionable and

harmful insects, on the other hand surgery successfully enlisted the aid of flesh flies (*Calliphoridae*) to cure gangrenous infections and osteomyelitis when the knife failed.

Everything man eats, wears, or uses is subject to the destructive ravages of insects; and the yearly toll amounts to hundreds

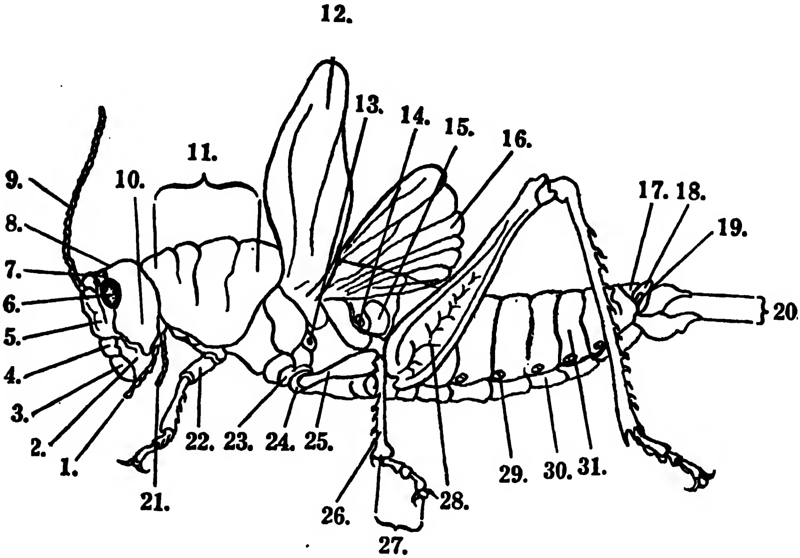


Fig. 56. The external features of a grasshopper. 1. Maxillary palpus; 2. Mandible; 3. Labrum or upper lip; 4. Clypeus; 5. Frons; 6. Compound eye; 7. Ocellus or simple eye; 8. Vertex; 9. Antenna; 10. Gena or cheek; 11. Pronotum; 12. Tegminum or wing cover; 13. Spiracle; 14. Spiracle; 15. Tympanum or ear drum; 16. Flying wing; 17. Supra-anal plate; 18. Podical plate; 19. Cercus; 20. Ovipositor; 21. Labial palpus; 22. Femur; 23. Coxa; 24. Trochanter; 25. Femur; 26. Tibia; 27. Tarsus; 28. Femur of middle leg; 29. Spiracle; 30. Sternum of abdomen; 31. Tergum of abdomen. After Turtox key card, courtesy Gen. Biol. Supply Co.

of millions of dollars. But again the beneficial activities of certain insects in cross-pollinating flowers of fruits, clover, and other plants cannot be measured. In addition to serving as food to birds and many other animals, they are the sources of many products which man uses. Among these are honey, shellac, silk, dyes, and medicines. However, the most valuable service rendered by insects is not evident to the ordinary observer. While a great number of insects are exceedingly destructive, there are others which render a great service to man by their habits of parasitizing and feeding upon harmful members of their kind.

The insects are so diverse, so numerous, so widely spread, and so closely interrelated with the lives of other animals and plants that, if some great catastrophe were to suddenly remove them from the fauna, the balance of nature would be more greatly disturbed than by the removal of any other animal group, probably including man himself.

Aside from the economic aspects of insects, their study will reveal the most interesting analogies, the most mechanically efficient social organizations, the most spectacular colors and structures, and the most captivating behaviorisms.

Insects were the first agriculturists (leaf-cutter and harvester ants), bakers (scarab beetles), confectioners (bees, honey ants), illuminating engineers (click beetles, fireflies), aeronauts (dragon flies), and musicians (crickets, katydids, cicadas, etc.). They had the first cafeterias (ants); they built the first complex houses (bees, wasps, termites); they had the first armies (ants); they originated gas warfare (bombardier beetles); and they were the first masters of slaves (ants).

Since they are the most numerous, the most accessible, and, next to man, the most important animals, it is only proper that the naturalist become familiar in general with their structures, their habits, and their more common representatives.

Insects may be collected in all places and at all seasons, and the student should derive a real pleasure from observing and collecting them.

Parts of an Insect

What is an insect? We have already learned that an insect may be distinguished from other animals by the fact that the body is divided into three usually evident regions; viz., head, thorax, and abdomen. The head is usually prominent and bears the mouth parts, compound eyes, ocelli, and antennae (Fig. 58). Insects usually have one pair of compound eyes and a variable number of ocelli or simple eyes, although the usual number is three. The ocelli are usually lacking in beetles, however. There is but one pair of antennae or feelers which are diverse in size, form, and insertion on the head among the various kinds of insects.

The six legs are attached to the middle region or thorax which has three segments. The front legs are articulated to the *prothorax;* the middle legs are on the *mesothorax;* and the hind legs are on

the *metathorax*. The thoracic segments are fused together so as to be invisible in many higher insects. They are distinct, however, on Thysanurans and some other generalized insects.

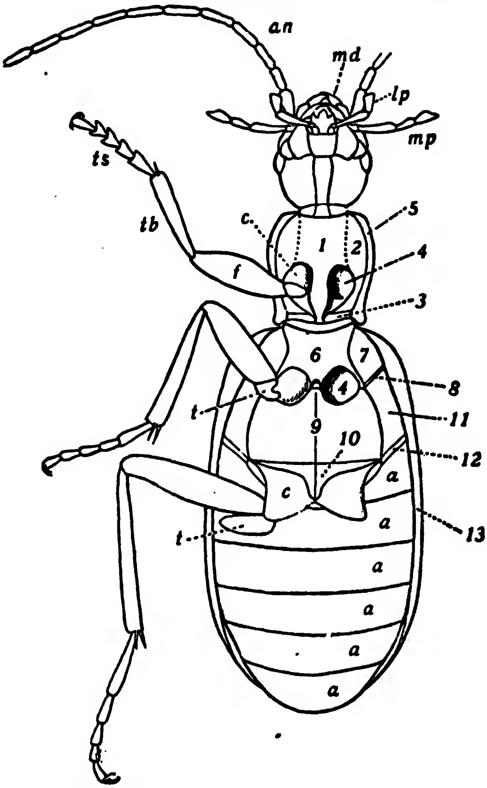


FIG. 57. Beetle anatomy. *1.* Prosternum; *2.* Proepisternum; *3.* Proepimeron; *4.* Coxal cavity; *5.* Inflexed side of pronotum; *6.* Mesosternum; *7.* Mesoepisternum; *8.* Mesoepimeron; *9.* Metasternum; *10.* Antecoxal piece; *11.* Metaepisternum; *12.* Metaepimeron; *13.* Inflexed side of elytron or wing cover; *a.* Sternum of abdominal segment; *an.* Antenna; *c.* Coxa; *f.* Femur; *lp.* Labial palpus; *md.* Mandible; *mp.* Maxillary palpus; *t.* Trochanter; *tb.* Tibia; *ts.* Tarsus. From Folsom and Wardle, *Entomology*, courtesy P. Blakiston's Son & Co.

Most insects have wings, although there are numerous wingless forms, as explained later. As a rule there are two pairs of wings, one pair attached to the mesothorax and the other to the metathorax. The order Diptera has only one pair of wings, the second pair having been replaced by halteres or balancers which are attached to the metathorax. The wings, too, are so variable in form and function as to warrant a separate discussion.

The abdomen is the posterior body region, and it is usually distinctly segmented. The number of segments varies; but the usual number is ten, although this number is not always visible. The abdomen sometimes carries appendages which occur, with few exceptions, at or near the caudal end. These appendages consist of genitalia, or external processes connected with the reproductive organs; bristle- or hair-like *cerci* (May flies, stoneflies, Thysanurans), which are usually sensory; and caudal filaments (pseu-

docerci). In larvae and in a few adults there may be breathing tubes (mosquito larvae, water scorpion), filamentous gills (May fly larvae), leaf gills (damsel fly nymphs), and other structures described later on.

The genitalia differ in the sexes. In the male they consist of penial structures and claspers, while in the female they are ovipositors. In some insects, such as bees, sawflies, and ichneumon flies, the ovipositors are modified for sawing, boring, or stinging.

In addition to the above-mentioned abdominal appendages there are others which are restricted to comparatively few individuals. Among these is the spring or leaping organ on the springtails (*Collembola*). An unusual set of very much reduced abdominal appendages occurs on a few insects. These are small, hair-like *styli* which occur on the ventral side of the abdominal segments of certain primitive wingless insects (*Thysanura*). These are said to be the vestiges of abdominal legs, and they indicate the primitive character of these wingless insects.

In some larvae, such as caterpillars and the larvae of gall flies and sawflies, there occur fleshy structures which serve as legs. These are prolegs and must not be considered as being true legs.

The outstanding anatomical features of specific insects are presented in individual discussions.

Mouth parts. There are two distinct types of mouths among insects—mandibulate or chewing mouths, and suctorial or sucking mouths. While these vary considerably, each type is easily distinguished.

The mouth consists of: (1) the upper lip or *labrum*, a movable flap attached to the clypeus; (2) the horny *mandibles* or first pair of jaws; (3) a bristle-covered, toothed *epipharynx* beneath the labrum and above the pharynx; (4) the *maxillae* or second pair of jaws, which are more complex than the mandibles. Each maxilla consists of three parts, *palpus*, *galea*, and *lacinia*, which are borne on the *stipes* or footstalk and attached to the skull by the *cardo* or hinge. (5) The labium, or lower lip, which is, in a way, similar to the maxilla and composed of the *mentum*, *submentum*, *palpiger*, *glossa*, *paraglossa*, and *palpus* (Figs. 59–60).

The tongue or hypopharynx is a fleshy organ more or less united with the base of the labium.

In the mandibulate or chewing insects the above parts are usually distinct. In the sucking insects, however, there are highly

specialized modifications of these parts, and homologies are frequently difficult to determine because of the fusion of some of them.

Suctorial mouth parts are specialized in bugs, flies, fleas, butterflies, and moths. In hymenopterous insects, thrips, and springtails, they are less specialized or somewhat modified.

In the beetles, earwigs, termites, book lice, roaches, grasshoppers, crickets, and katydids, the mandibulate or chewing mouth parts are characteristic. In many insects, such as May

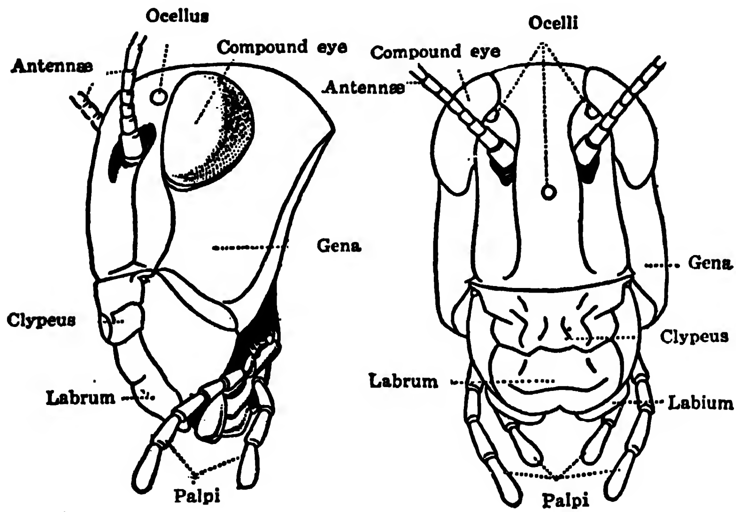


FIG. 58. The head of a grasshopper. After Folsom and Wardle, *Entomology*, courtesy P. Blakison's Son & Co.

flies and many moths, in which the adult lives for a short time only, the mouth parts are undeveloped, and the insects never feed. In fly larvae, the mouth parts are very simple, especially in those species which breed in carrion or other immediately available soft food which requires no biting or chewing. In the dobson fly (*Corydalus*), the larva has powerful, functional jaws; but in adult males the jaws are greatly modified, and they are non-functional. The types are shown in Figs. 43, 59, 60, 111.

Legs. The insect has six legs, all of which are attached to the thorax or middle body region. Each leg consists of five principal segments; viz., the *coxa*, which articulates the leg to the body; a second triangular segment, the *trochanter*; the *femur* or thigh; the

tibia, which is usually more slender than the femur; and the *tarsus* or foot, which is usually composed of five smaller segments and which bears the claw (Fig. 56). In all insects these segments differ in size, shape, length, and form. The legs are frequently modified for seizing (mantis, giant water bug), for swimming (dytiscid beetle, water boatman, backswimmer), for running (ground beetles, roaches, tiger beetles), for walking (walking-stick), for digging (mole cricket, scarab beetles), and for jumping (grass-

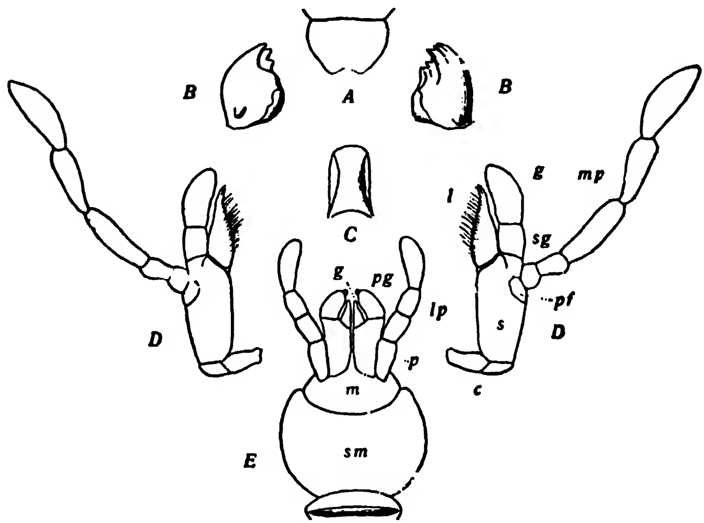


Fig. 59. Mouth parts of a roach. *A.* Labrum; *B.* Mandibles; *C.* Hypopharynx; *D.* Maxilla; *E.* Labium; *c.* Cardo or hinge; *s.* Stipes or footstalk; *pf.* Palpifer; *g.* (*D*) Galea; *sg.* Subgalea; *l.* Lacinia; *mp.* Maxillary palpus; *sm.* Submentum; *m.* Mentum; *p.* Palpiger; *lp.* Labial palpus; *g.* (*E*) Glossa; *pg.* Paraglossa. After Folsom and Wardle, *Entomology*, courtesy P. Blakiston's Son & Co.

hopper, cricket, katydid). In the grasshoppers the long hind legs also serve as a prop when the insect is standing on a vertical stalk of grass.

Occasionally the legs exhibit secondary sexual characters. For instance, in the dytiscid and gyrinid beetles the males have clasping structures on the tarsi (Fig. 39). In the fruit flies (*Drosophilidae*) and the long-legged flies (*Dolichopodidae*), the front tarsi of the males are elongated and ornamented with hairs. In certain locusts there are stridulating or sound-producing structures. These consist of a row of minute spines on the inner sides of the

hind femora. The legs of dragon flies fold so as to form a basket in which captured food is carried. In crickets and katydids the *tympana* (sing. tympanum), or ear drums, are located on the legs (Fig. 79), while in honey bees the legs are greatly modified for gathering pollen, cleaning the antennae, and manipulating the wax (Fig. 152). The tumble bugs (scarab beetles) usually have no front tarsi, and the distal ends of the tibiae are toothed, the teeth serving as "rakes" in removing stringy material from the food (Fig. 134).

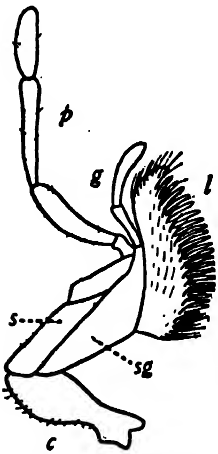


FIG. 60. Maxilla of ground beetle. *p.* Palpus; *l.* Lacinia; *g.* Galea; *sg.* Subgalea; *s.* Stipes; *c.* Cardo. After Folsom and Wardle, *Entomology*, courtesy P. Blakiston's Son & Co.

Frequently the legs are hairy or carry spines. The tarsus usually bears one or two claws between which on the underside there are sometimes cushion-like pads called *pulvilli.* Glandular hairs are occasionally present on the pulvilli. These secrete an adhesive substance which enables such insects as flies to walk upside down on the undersides of objects.

In addition to the thoracic legs, many larvae (especially caterpillars) have fleshy prolegs on other segments of the body. The larvae of flies, of many beetles, and of most hymenopterous insects are legless.

Most of these characters and adaptations are discussed and described in connection with individual insects. The adaptive features of the legs usually indicate the habits and habitats of individuals and assist generally in determining environmental relationships.

Eyes. The eyes of insects are of two kinds; viz., simple eyes, or ocelli, and compound eyes. Both kinds vary somewhat in size and position, according to habits, haunts, and species. There are always two compound eyes, except in a few blind insects; and they are, as a rule, the more prominent.

An examination of the eye of an insect will reveal that it has numerous *facets* (Fig. 61) each of which has a hexagonal shape. The number of facets ranges from one in the workers of certain ants to 2500 in the grasshopper, 4000 in the housefly, 17,000 in the *papilio* butterfly, and 25,000 in the beetle, *mordella.*

The facets are the corneal ends of rod-like structures called

ommatidia, each of which is a separate eye with a cornea, a crystalline cone or lens, and a retinula. The surface of the facet or cornea is convex, and there is no compensating shutter of focusing apparatus. Therefore the focus is fixed; and the convexity of the cornea makes the insect short-sighted.

The compound eyes may be round, oval, kidney-shaped, or triangular. They may be close together as in most dragon flies

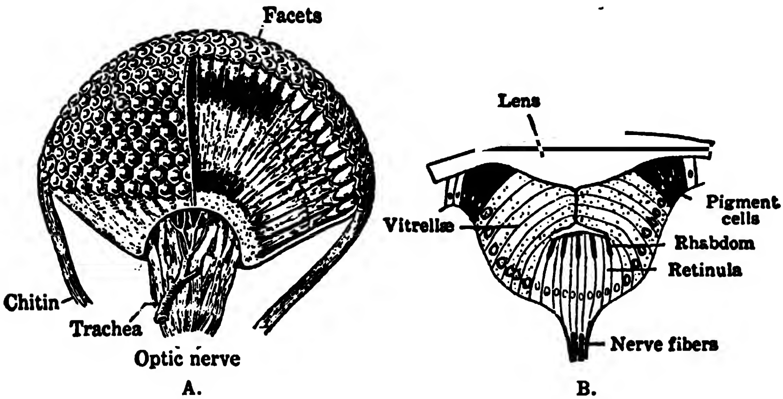


FIG. 61. Diagrams of insect eyes. A. Compound eye; B. Simple eye or ocellus. From Hegner, *Invertebrate Zoology*, A. after Schmeil and B. after Borradaile and Potts.

or widely separated as in damsel flies and in the tropical, stalk-eyed flies (Fig. 55). Sometimes, as in whirligig beetles and May flies, the eye is completely divided into two separate lobes (Fig. 28). There is frequently a difference between the eyes of males and females, the males usually having larger eyes with more facets. The drone bee, for instance, has much larger eyes than does the queen (Fig. 62). Even the facets may vary in the same eye, those on one side being larger than the facets on the other side.

The position of the eyes is dependent upon the habits of the insect. They may be on the front, underside, or upperside of the head; but they are always in a position where most effective.

Experimental evidence suggests that the compound eyes are chiefly detectors of movement and that definite images play only a subordinate rôle in vision.

One might be led to believe that, since each ommatidium is a separate eye, the insect would see an object hundreds of times all

at once, but such is not the case. Each ommatidium contributes to a general image by recording only a part of an object looked at. In other words, with the great number of ommatidia, each capable of sight perception, the image formed is a combined one or a mosaic, each ommatidium recording only a part of the object.

Sometimes nocturnal insects have a reflecting structure or *tapetum* which increases the intensity of faint light by causing it

FIG. 62. Heads of queen bee (left) and drone (right) showing differences in size of eyes, insertion of antennae, and simple eyes or ocelli. After Cheshire from Folsom and Wardle, *Entomology*, courtesy P. Blakiston's Son & Co.

to pass through the crystalline cone twice. The glowing eyes of moths in light reveal the tapetal structure.

The simple eyes are called *ocelli*, and they vary in number and position. There are usually three ocelli, however; and these are generally located on the frons or vertex. In most beetles the ocelli are absent, and there are lateral ocelli on the heads of many caterpillars. Each ocellus is capable of light perception, and its construction is somewhat similar to an ommatidium. The ocelli seem to function, primarily, in detecting light intensities.

Wings. The wings are primarily used for flight, but there are to be seen in them numerous modifications for other purposes. Insects usually have four wings (two pairs), one pair attached to the mesothorax and one pair attached to the metathorax. However, the dipterous insects have only one pair of true wings and a second pair of "balancers" or halteres. These are visible on the giant cranefly shown in Fig. 37.

In the more primitive orders of insects (*Thysanura, Collembola*) there are no wings at all. In some of the higher winged orders there are apterous individuals which have lost their wings through

disuse. Among these are bedbugs, aphids, and the females of the tussock, cankerworm, and bagworm moths.

In beetles, grasshoppers, and earwigs the front wings are thick and horny and serve to protect the membranous flying wings which fold beneath them. In these the front wings are not organs of flight. They are held forward so as not to interfere with the vibration of the hind wings, and they function as gliders and balancers. You have probably noticed that a May beetle falls

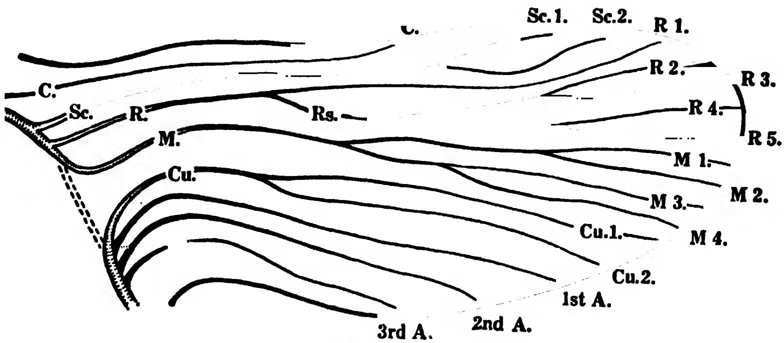


FIG. 63. A primitive insect wing showing numerous veins. Compare with the wing of a bee. C. Costa; Sc. Subcosta; R. Radius; M. Median; Cu. Cubitus; Rs. Radial Sector; A. Anal. After Comstock.

when it flies against an object. The contact causes the front wing to interfere with the vibratory movements of the hind wing.

The wings are considerably reduced and shortened in the rove beetles (*Staphylinidae*), some short-winged grasshoppers, earwigs, and in thrips (*Thysanoptera*), while in many other insects the wings are the seat of sexual adornment, the male being, as a rule, the more brilliantly colored.

Sometimes the wings are hairy, as in caddis flies and mosquitoes. In moths and butterflies the scales carry the color properties. In all cases the wings are mechanically adapted to flight, being strengthened at their anterior margins by heavy costal veins and supplied with cross veins to add rigidity.

In the four-winged insects, the synchronous vibration of the wings is effected in several ways. In bees there is a row of hooks called *hamuli* on the anterior or costal margin of the hind wing. In flight, these hooks fasten in a fold on the posterior or anal margin of the front wing, holding the wings together (Fig. 64).

In most moths there is a bristle-like structure in the humeral angle of the hind wing. This projection is called a *frenulum*, and it catches in a membranous fold on the front wing and serves to hold the wings together in flight (Fig. 64).

On the fore wing of the hepialid moth, the posterior lobe is modified into a slender, finger-like structure called the *jugum* which slips under the anterior margin of the hind wing.

The dobson fly has a structure called the *fibula* on the posterior margin of the front wing. This clasps an elevated vein on the hind wing and serves to hold the wings together.

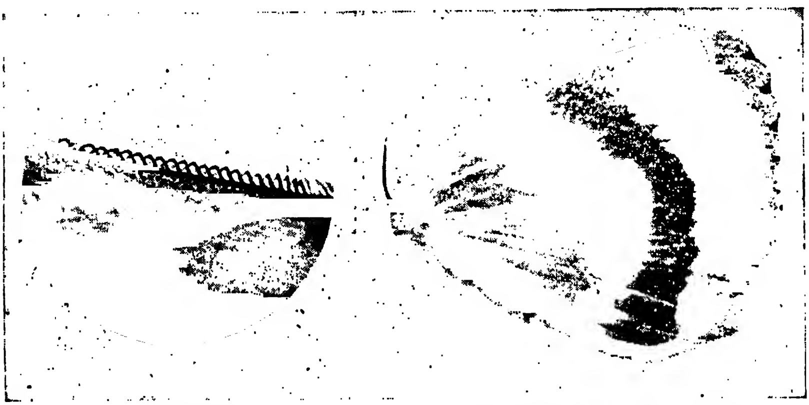


Fig. 64. Wing structures. Hamuli on hind wing of a bee, at left (Photomicrograph); Frenulum on hind wing of a moth, at right (enlarged).

The veins in the wings are developed chiefly along the tracheae or respiratory structures, and their number and modifications are the absolute bases of identification in some insect groups. The venation is sometimes an indication of the primitive or highly specialized character of insects, the more primitive forms usually having a greater number of veins. A typical primitive wing, with the principal veins named, is shown in Fig. 63. A specialized wing such as that of a hymenopterous insect is shown in Fig. 150.

It might be added that the positions of the wings at rest are variable and serve to aid in the quick identification of such insects as moths, butterflies, damsel flies, and dragon flies. The experienced collector of insects is usually able to recognize the kinds of insects by their flight characteristics. These vary so much that numerous species of all groups have flight manners so distinctly individual as to make them readily identifiable while they are on

the wing. A knowledge of flight characters adds greatly to success in collecting with a net, especially in the cases of certain dragon flies.

Antennae. There are many types of antennae or feelers (Fig. 65). In some insects, such as long-horned beetles and caddis flies, they

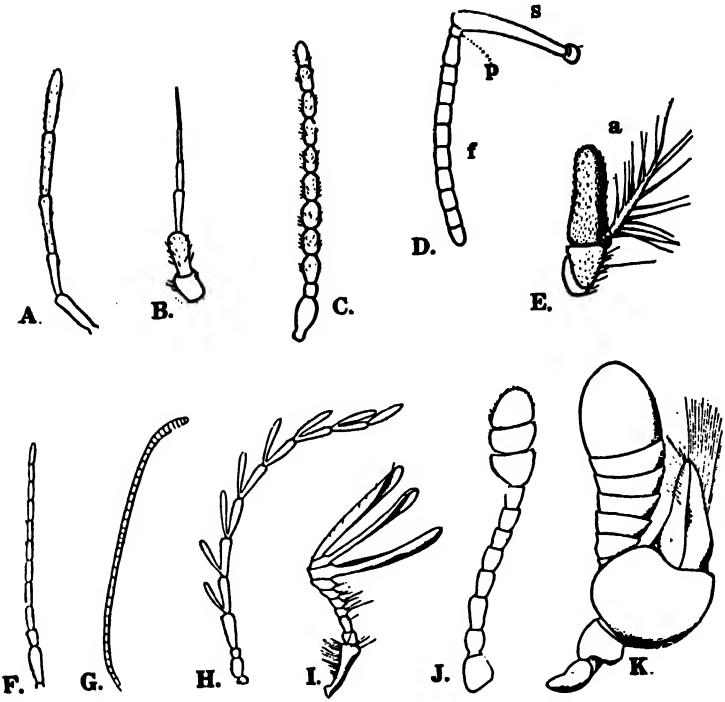


Fig. 65. Types of antennae. A. Filiform (stink bug); B. Setaceous (dragon fly); C. Moniliform (dermestid beetle); D. Geniculate (bee); f. Flagellum; p. Pedicel; s. Scape; E. Irregular (carrion fly); a. Arista; F. Setaceous (ground beetle); G. Clavate (monarch butterfly); H. Pectinate (beetle); I. Lamellate (June beetle); J. Capitate (Erotylid beetle); K. Irregular (Gyrinid beetle). After Folsom and Wardle, *Entomology*, courtesy P. Blakiston's Son & Co.

may be considerably longer than the body, while in the fast-flying dragon flies they are reduced to mere bristles. Long antennae would seriously impede the flight of dragon flies. The size, form, and insertion of the antennae are different in the various species; and frequently they are dependent on the habits of the insects and the function of the antennae themselves.

In many insects such as grasshoppers the antennae are real

feelers and are tactile. In many moths, aphids, and beetles they are olfactory and bear smelling organs which are usually in the form of olfactory pits. In the June beetle there are nearly 40,000 of these pits on each antenna. The antennae of hydrophilid beetles are respiratory, and those of the male blister beetle (*Meloe angusticollis*) are adapted to hold the female during coition. This is also the case in certain springtails.

There are distinct sexual differences in the antennae in many insects. In moths the male antennae are usually much more feathery than those of the female. The male mosquito has plumose antennae, and those of the female are thread-like. In mosquitoes the antennae are auditory. They may be likened to sending and receiving sets. The female, during the mating season, produces sounds by vibrating her thread-like antennae. During this period the susceptible males hold their plumose antennae erect and receive the sound waves sympathetically. In this way the sexes are drawn together.

The antennae are composed of a varying number of segments, all of which are not necessarily alike. In fact the number, size, and shape of the segments are frequently of importance in identifications. The nomenclature of the regions of the antenna are shown in Fig. 65.

How insects breathe. The respiratory system of insects in some ways resembles the plumbing of a building inasmuch as it consists of a network of tubes or "pipes" which ramify through the entire body, conducting the life-sustaining oxygen to all tissues and organs. These carrying tubes are connected with main lines or trunks which are in turn connected with the outside. If you will examine the sides of a grasshopper's abdomen, you will see what appear to be tiny pores, a pair to each segment (Fig. 56). These are the *stigmata* or *spiracles*, which are openings of tubes which lead to larger tubes within the body. In a typical insect there is a pair of spiracles to each body segment and two main, longitudinal tubes, one on each side, with which the external openings connect. The larger, internal tubes are called *tracheae;* and from them are myriads of ultra-microscopic branches which reach all body tissues. These minute branches are called *tracheoles,* and they perform the real respiratory functions (Fig. 66). Air is drawn into the body through the spiracles, and is conducted to the tracheae and then into the tracheoles. You have probably

noticed how wasps and butterflies raise and lower their abdomens when at rest. They are pumping air into the body. Specialized muscles and "pumping sacs" assist in forcing the air through the tracheae. Since most insects are specialized, few of them have the typical number of spiracles; and there are also vast modifications of the internal system with which we are not particularly concerned here. In a few insects the system is independent for each abdominal segment.

The number and position of the spiracles are quite variable; and in adult aquatic forms, such as beetles and water bugs, they are usually on the upper surface of the abdomen so that the folded wings cover them and thus prevent water from entering them.

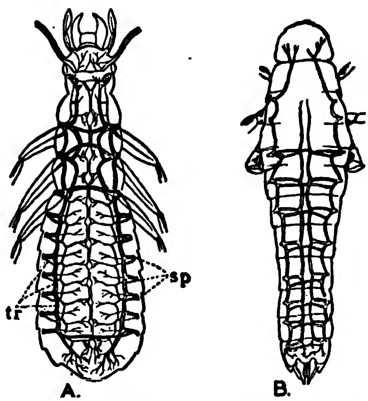


FIG. 66. The breathing systems of insects. A. Tracheal system of a beetle; B. Locust tracheal system; tr. Trachea; sp. Spiracles. A. after Kolbe; B. after Snodgrass.

The light oils which are sold as "fly sprays" are partially efficacious in that the insects inhale the tiny globules of oil into the spiracular openings, and the insect suffocates because its breathing "pipes" are clogged. These sprays usually contain poisonous substances as well. The recent insecticides, however, are "contact poisons" which are designed to penetrate the outer skeleton. A light oil is used as a carrier for poisons such as pyrethrum which affect the nervous system. Birds may be frequently seen "dusting" themselves, and sometimes finely powdered clay or soot is dusted on the plants to kill insect pests. The fine particles of dust also choke the tracheae and kill the insects, although the spiracles usually have fine hairs to prevent the dust from entering the main tracheae.

Since the most extensive modifications of the respiratory system occur in aquatic insects, these will be discussed in detail in the chapter devoted to water animals.

THE DEVELOPMENT OF INSECTS

The eggs of insects. As a general rule insects lay eggs and are therefore oviparous, although in a number of forms, notably flesh flies and aphids, the young are frequently born alive.

The eggs are of various sizes and shapes according to the kind of insects; and they are often as spectacular as snowflakes in form (Fig. 67). The number of eggs also varies and ranges from one in the sheep "tick" (*Melophagus ovinus*—Diptera) to thousands in ants and termites. Among the solitary insects such as certain mud wasps, where one or both parents provide for the offspring, the number of eggs is reduced. Except in rare cases (e.g., Chalcid flies) only one insect comes from each egg. When one egg produces more than one individual, they are always of the same sex and the process is called polyembryony.

Egg-laying habits of insects. There is also a great diversity of habit in laying eggs, and each female insect is equipped with a

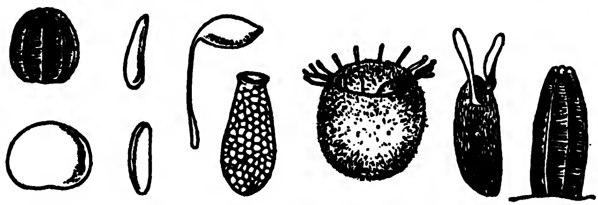


FIG. 67. Types of insect eggs. After Folsom and Wardle, *Entomology*, courtesy P. Blakiston's Son & Co.

special apparatus called an ovipositor for depositing them. The dragon fly may be seen striking the water in quick succession with the abdomen curved downward with her ovipositor. Or she may be seen to descend beneath the surface (sometimes dragging the male with her) where she attaches her eggs to a submerged object.

The katydid attaches her eggs around the margin of a leaf, while the walking-stick merely drops her eggs to the ground where they lie for two years before hatching. The female grasshopper inserts her whole abdomen into moist, rich earth and deposits her eggs in the depression (Fig. 69). The sticky covering of the eggs collects particles of dirt which enclose the mass in a finger-like capsule. The cockroach secretes a curious capsule (oötheca) in which the eggs are encased (Fig. 80). She carries this capsule on the tip of her abdomen until a few days before the eggs are ready to hatch, and then she inserts the capsule in a dark, warm, dry crevice. The long, black ovipositor of the female cricket is used to deposit the eggs in sandy soil. Many insects lay their eggs in the bodies of other insects (Figs. 7, 8, 9). The ichneumon flies which have long, thread-like ovipositors lay their eggs in the backs of

caterpillars; and some species, including *Thalessa*, even drill into hardwood trees to leave their eggs in the burrows of other insects (Fig. 143). The cicada, a seventeen-year locust, deposits her eggs in a slit which she makes in a twig. The blowfly lays its eggs in the nostrils of sheep, and the warble flies lay their eggs on the hairs of rats, rabbits, horses, and cattle. The mantis attaches its eggs in elongated masses on twigs, covering them with a silken material, while the spittle insects (froghoppers—*Cercopidae*,

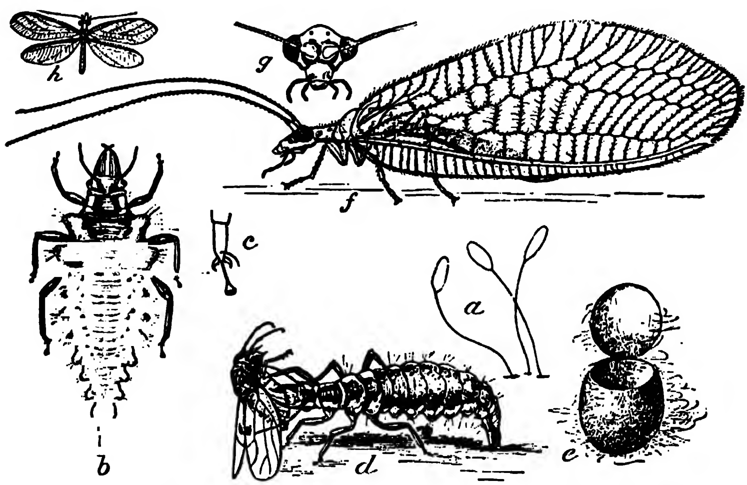


FIG. 68. The life history of the lace-wing, *Chrysopa* (Neuroptera-*Chrysopidae*). *a.* Eggs on stalks; *b.* Larva; *c.* Tarsus; *d.* Larva devouring an aphid; *e.* Cocoon; *f.* Adult with wings at rest; *g.* Head; *h.* Adult with wings expanded. After Chittenden, courtesy Bur. Ent., U. S. Dept. Agric.

Homoptera) (Fig. 88) and certain moths (*Heterocampa*) cover their eggs with froth. The female water bug is hesitant to lay her eggs just anywhere, lest they be devoured by other animals; so whenever possible she seizes an unwary male and glues her eggs all over his back (Fig. 33). This renders his wings useless, and he is forced to remain in the water until the young are hatched.

One of the most interesting methods of egg laying is to be seen in the lace-wing fly (*Chrysopa*) (Fig. 68). The female seems to realize that if she laid all of the eggs together on the surface of a twig, the one first hatched would eat up all of its potential brothers and sisters; and so she safeguards against this by placing each egg on a hair-like stalk. The newly emerged young, called an aphis lion, descends the supporting thread and goes about the surface of

the leaf or stem feeding upon plant lice. Many insects, such as coddling moths and chestnut beetles, deposit their eggs in the fruits and flowers, while others attach them in clusters to the surfaces of leaves and stems. Mosquitoes make floating rafts of their egg masses, while gall-makers lay their eggs in the stems or leaves of plants.

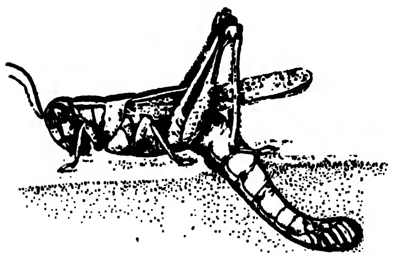


FIG. 69. A locust depositing eggs in the soil. Courtesy U. S. Dept. Agric.

These examples serve to show that in general the egg-laying habits are interesting as well as diverse. The oviposition of many other insects is described in the discussion of groups and species later on.

Hatching of the eggs (eclosion). The duration of the egg state is dependent upon several factors, such as kind of insect, temperature, and humidity. The walking-stick remains in the egg for two years, while some flies hatch within a few hours. Many of our insects pass the winter in the egg. Since most eggs have a tough shell or covering, the manner of eclosion is of interest, although not a great deal is known about it. Many larvae eat their way out, while the contortions of the developed young within often break the shell. Some fly larvae have swellings on their heads with which they bombard an opening, while flea larvae are equipped with a temporary knife-like structure on the head which cuts an opening as the head is moved. The egg usually has a hatching line or suture along which the shell is weaker. The movements of the young inside usually cause the egg to open along this line.

FIG. 70. The saddle-back caterpillar, *Sibine stimulea* (*Eucleidae*). Courtesy U. S. Dept. Agric.

The metamorphosis of insects. When the young insect emerges from the egg, it may or may not resemble its parents; and whether it does or not, the youngster must pass through certain stages before it is mature. In those insects where the larva or young in no way resembles the parents, these stages are quite pronounced, while in others the stages may be gradual transformations. This development is known as metamorphosis (*meta*—"beyond"; *morphos*—"form").

Since the chitinous skeleton is on the outside, the insect must shed it from time to time in order to allow growth. A special

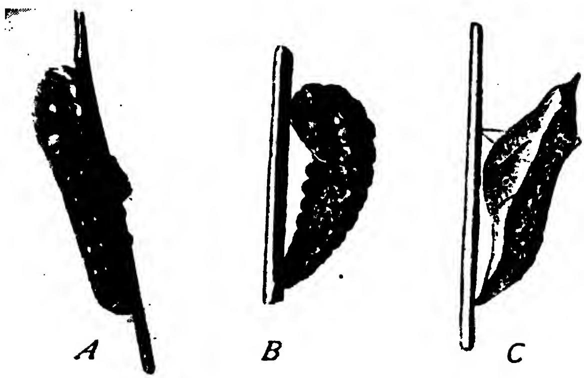


FIG. 71. A swallowtail butterfly, *Papilio troilus* (*Papilionidae*). *A*. Larva; *B*. Larva suspended for pupation; *C*. Chrysalis. From Folsom and Wardle, *Entomology*, courtesy P. Blakiston's Son & Co.

glandular secretion, known as the molting fluid, assists in casting off the outer skin. The process of shedding the skin is known as molting or *ecdysis;* and the cast-off skin is called an *exuvium.* The number of ecdyses is usually from four to six times, but in frequent cases it is many more, being at least twenty in a certain May fly. In nearly all cases there is some change in the insect after each molt, so the intervals between ecdyses are called *stadia,* and the form of the insect in the stadium is called the *instar.*

In the wingless insects such as silver fish, springtails, head lice, and biting bird lice, there are no marked changes in the development; and the young are images of their parents. These forms are said to be *ametabolous* (without change).

Paurometabolous (gradual change) insects are those which undergo gradual changes in their development. The young of these

are called nymphs, which resemble the parents except for the fact that they are small and disproportioned, and they lack wings. For example, the young grasshopper is easily recognized as such; but it usually has to molt six times before it is a mature insect with wings and well-proportioned parts. After each molt the increasing development is noticeable. All of the Orthoptera, termites, earwigs, book lice, bugs, and thrips undergo this gradual metamorphosis.

In certain insects such as stoneflies, May flies, and dragon flies there are not four distinct stages in development; and yet the transformations are more pronounced than those of paurometabolous forms. The young of these are called nymphs (naiads by Comstock), and the insects are said to be *hemimetabolous* (half change). Among flies, beetles, and butterflies there are four distinct stages in development; viz., egg, larva, pupa, and adult. Such metamorphosis is called *holometabolous* (whole change) development, or complete metamorphosis (Fig. 72). In some insects, notably blister beetles, strepsipterans, some species of neuroptera (*Mantispa*), and a few parasitic wasps, the larva undergoes a development in which each instar differs from the preceding one. This development is known as *hypermetamorphosis*. The details of the changes are included in the discussions of the orders.

FIG. 72. Tobacco worm-hawk moth, *Phlegethontius celeus* (*Sphingidae*). Courtesy Bur. Ent., U. S. Dept. Agric.

Insect larvae. The larva is the second stage in the development of holometabolous insects. While they are usually called "worms" such as "cabbage worms," tomato worms, wireworms, chestnut worms, etc., they differ from worms in that they have fewer segments and fairly well-developed mouth parts. They usually have eyes, a well-developed head, and legs or leg-like appendages. There

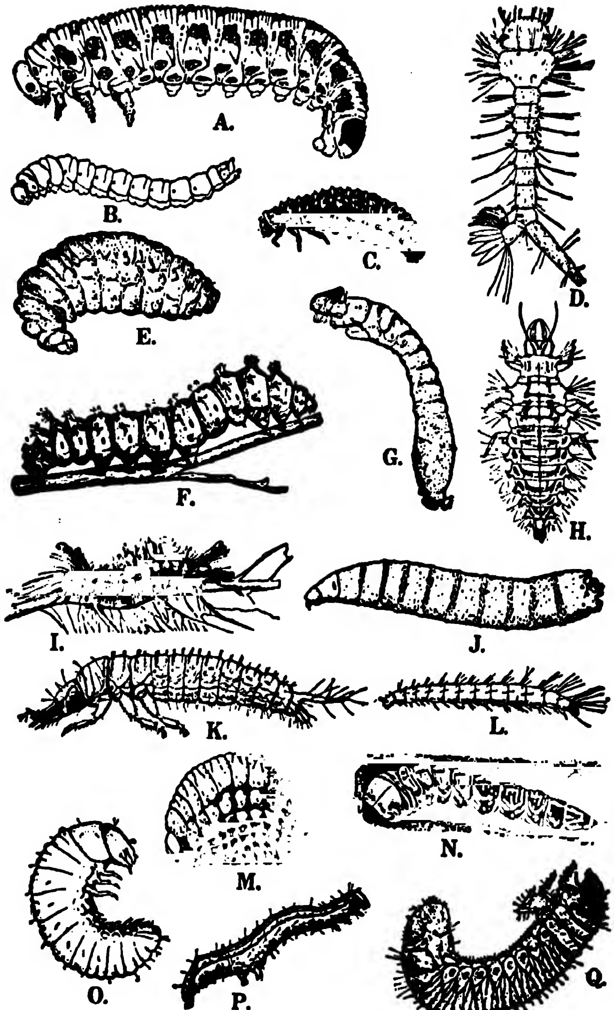


FIG. 73. Types of larvae. A. Sawfly (Hymenoptera); B. Sawfly; C. Digger wasp, *Tiphia* (Hymenoptera); D. Beet leaf beetle (Coleoptera); E. Mosquito (Diptera); F. Cecropia moth (Lepidoptera); G. Black fly (Diptera-*Simuliidae*); H. Lace-wing (Neuroptera-*Chrysopidae*); I. Tussock moth (Lepidoptera); J. Apple maggot (Diptera); K. Ground beetle (Coleoptera-*Carabidae*); L. Flea (Siphonaptera); M. Beetle, *Colaspis brunnea* (Coleoptera-*Chrysomelidae*); N. Weevil or snout beetle (Coleoptera-Rhyncophora); O. Prionid beetle (Coleoptera-*Prionidae*); P. Alfalfa looper (Lepidoptera); Q. Scarab beetle (Coleoptera-*Scarabaeidae*). From Metcalf and Flint, ***Fundamentals of Insect Life***, courtesy McGraw-Hill Book Co.

are numerous types of larvae, a number of which are discussed and figured on Fig. 73.

The pupa. This is the so-called quiescent period in complete metamorphosis, during which time the insect undergoes its most

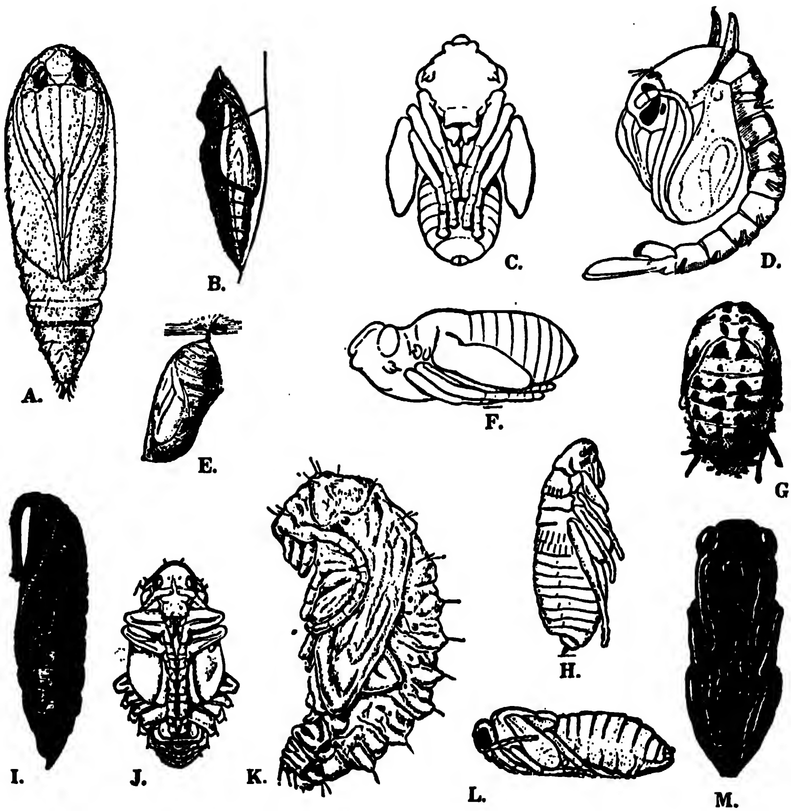


FIG. 74. Types of pupae. A. Bollworm moth (Lepidoptera); B. Tobacco worm moth (Lepidoptera); C. Alfalfa butterfly (Lepidoptera); D. Monarch butterfly (Lepidoptera); E. Beet leaf beetle (Coleoptera); F. Cherry leaf beetle (Coleoptera); G. Apple maggot (Diptera); H. Lateral view of apple maggot; I. Mosquito (Diptera); J. Flea (Siphonaptera); K. Pear slug (Lepidoptera); L. Lady bird beetle (Coleoptera); M. Hymenopteran. From Metcalf and Flint, ***Fundamentals of Insect Life***, courtesy McGraw-Hill Book Co.

remarkable development. The pupal period is physiologically the most active period in the life of an insect. It is in this stage that the compound eyes, antennae, true legs, and wings are acquired. There are several kinds of pupae, such as those of the beetles and

hymenopterous insects in which the legs and wings are free (exarate—beetles); those which have the legs glued to the surface (obtected—Lepidoptera); and those in which all appendages are confined within the pupal skin (coarctate—Diptera).

While most pupae usually remain inactive, there are some pupae, notably those of mosquitoes and certain midge flies, which move about but do not feed.

In quite a number of insects, the pupae are enclosed in cocoons of silk spun by the adult larva. This is especially true of most moths and many hymenoptera, while other insects use chips, mud, and other material in making cases in which to pupate. The silk of commerce is from cocoons of the silkworm, although the cocoons of Cecropia and Polyphemus moths are sometimes used.

The cocoon is marvelously constructed so that the weak, newly developed adult or imago can escape from it. The caterpillar sometimes provides for this by weaving a conical valve at one end (Promethea and Cecropia). In every other case where no valve is made the emerging form is equipped with toothed crests and hatching spines (Luna moth) or the adult (Polyphemus moth) softens the end of the cocoon with liquids so that the threads may be easily forced apart. Some common pupae are shown in Fig. 74.

The adult or imago stage of insects. While these are discussed in connection with certain commoner insects, it is well to remember that the primary purpose of the adults is to produce offspring. Most adults are short-lived, and many of them never feed. What strange forces of nature provide that so many forms spend 99 per cent of their lives in immature stages?

The size and color of adult insects is usually more or less constant, but temperature, food, and other factors effect variations which are marked. Then, too, there are distinct sexual differences in some insects which are so pronounced that unless one is aware of them he might mistake male and female for different species. Where there are several broods in a season, each brood may be different from the others. A common example of this is the cabbage butterfly (Fig. 123).

Newly emerged insects are usually light in color, but inasmuch as chitin seems to be affected by oxygen, the color darkens considerably after a few hours.

The Orders of Insects [1]

Thysanura (fringe tail). These are primitive, wingless insects represented by the "silver fish" or "fish moth" which is commonly found in dark places in ill-ventilated houses or under logs and stones outdoors. They are egg-laying insects but undergo no metamorphosis, the adults and young being alike except in size. Their mouth parts are adapted to chewing; in some species they are prominent, while in others they are sunken in the head and almost invisible. The divisions of the thorax are not fused together, and are distinctly visible. There are two common families—*Machilidae,* which is not found in houses, and *Lepismatidae,* which is sometimes a serious household pest, doing considerable damage to carpets, clothing, and books (Fig. 77).

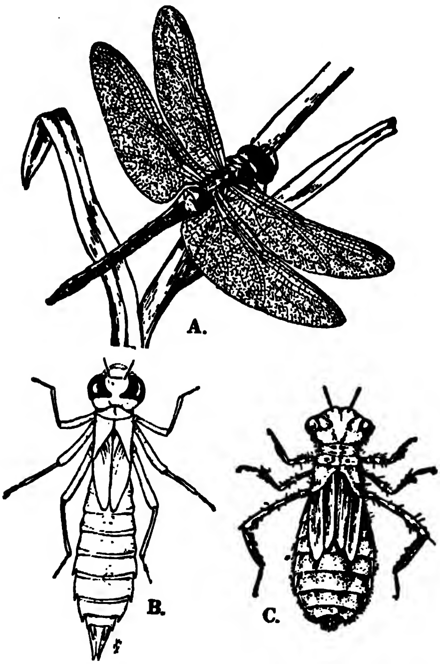


Fig. 75. A dragon fly. A. Adult; B. and C. nymphs. A., C. from Lutz, *Fieldbook of Insects,* courtesy G. P. Putnam's Sons; B. courtesy Gen. Biol. Supply Co.

Collembola (glue-bar). Minute whitish or blackish wingless insects differing from the Thysanura in that they have fewer abdominal segments and possessing a springing organ on the fourth abdominal segment. They occur in damp places under stones and dead leaves as well as in the crevices of bark. They are most frequently seen on the surface of ponds where they are accidentally transported, although they sometimes appear by thousands on the surface of snow. They are sometimes called snow fleas. Like the Thysanura they undergo no metamorphosis.

[1] It was not thought necessary to arrange the orders in an evolutionary sequence.

Orthoptera (straight-winged). This order is sometimes called the "singing order," and it includes the crickets, grasshoppers, katydids, cockroaches, walking-sticks, and mantids. These are all terrestrial insects with two pairs of wings that lie parallel to the body when at rest. The front wings are narrow and more or less thickened and stiffened. The hind wings are large and fan-shaped and fold up beneath the front wings when at rest. All the members are oviparous and undergo a gradual metamorphosis. The mouth parts are adapted to biting and chewing.

The order is, as a whole, a seriously injurious group, the mantises alone being beneficial. The wing differences, music-making, egg-laying habits, and leg modifications make the order an interesting one.

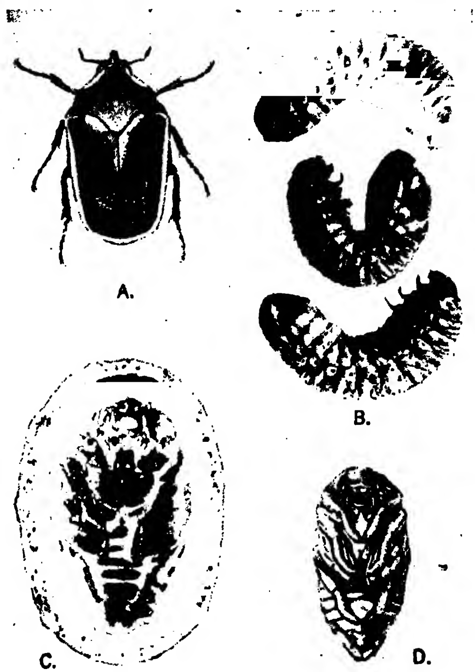


Fig. 76. The life history of the green June beetle (*Cotinus nitida*). A. Adult; B. Larva; C. Pupa in earthen cocoon; D. Pupa. After Chittenden, courtesy Bur. Ent., U. S. Dept. Agric.

The crickets (family *Gryllidae*) constitute a variable group (Fig. 79). They are chiefly nocturnal in their habits, and their dark color is of value in concealing them in the darkness. Their flattened bodies enable them to crawl under stones and other objects on the ground. The true crickets lack the flying hind wings and possess only the anterior wing covers, with which only the males sing. The females possess long ovipositors through which the eggs are deposited in loamy soil.

While field crickets sometimes invade houses, the "cricket on the hearth" of literature is usually a brownish exotic species. All are destructive to lace curtains, starched linens, book bindings, etc.

Crickets feed on vegetable matter and on other animals. Occasionally they are cannibalistic and eat each other. As indicated elsewhere, the ear drum is on the front leg (Fig. 79).

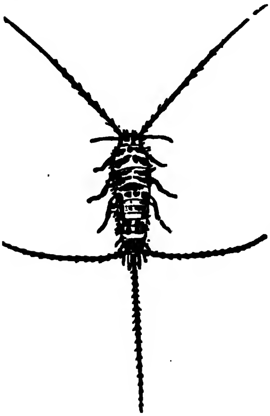


FIG. 77. A fish moth (*Thysanura*). After Howard and Marlatt, courtesy U. S. Dept. Agric.

The tree cricket (*Oecanthus*) is a delicate, light green insect with darker legs. It lives in flowers and in trees. The eggs are laid on stems, one species preferring the raspberry. Tree crickets sing in unison throughout the night.

The mole cricket (Fig. 79) is one of the most curious of American insects. The front tibiae are shaped like hands and are used for digging. The mole cricket feeds on the roots of plants; and while not so generally distributed, they sometimes appear in great numbers, even invading houses. The wings and antennae are short, and the insects are usually light brown in color.

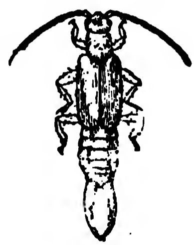


FIG. 78. An earwig, *Labia minor* (*Dermaptera*). After Lutz, *Fieldbook of Insects*, courtesy of G. P. Putnam's Sons.

The grasshoppers are of two kinds—the short-horned *Acrididae* and the long-horned *Tettigoniidae* (*Locustidae*) (Plate IX).

The true locusts are short-horned grasshoppers. There are many species of locusts, and all of them feed on plants, although they sometimes eat each other. The long horns include the false and true katydids, cone-headed and shield-backed grasshoppers, and the cave crickets or camel crickets. The latter are wingless inhabitants of caves, woods, and cellars. The short-winged grasshoppers are called "lubbers."

The short horns include the migrating forms, such as the Rocky Mountain locust, which devastate the crops over large areas. Nearly all of them devour green plants; and the katydid and true crickets can be destructive by laying their eggs in the stems of plants. Some of the locusts have gaily colored hind wings. Some representatives of both families are shown on Plate IX.

The walking-stick (*Phasmidae*) so resembles a twig that it usually escapes observation. It lives in the trees feeding upon the

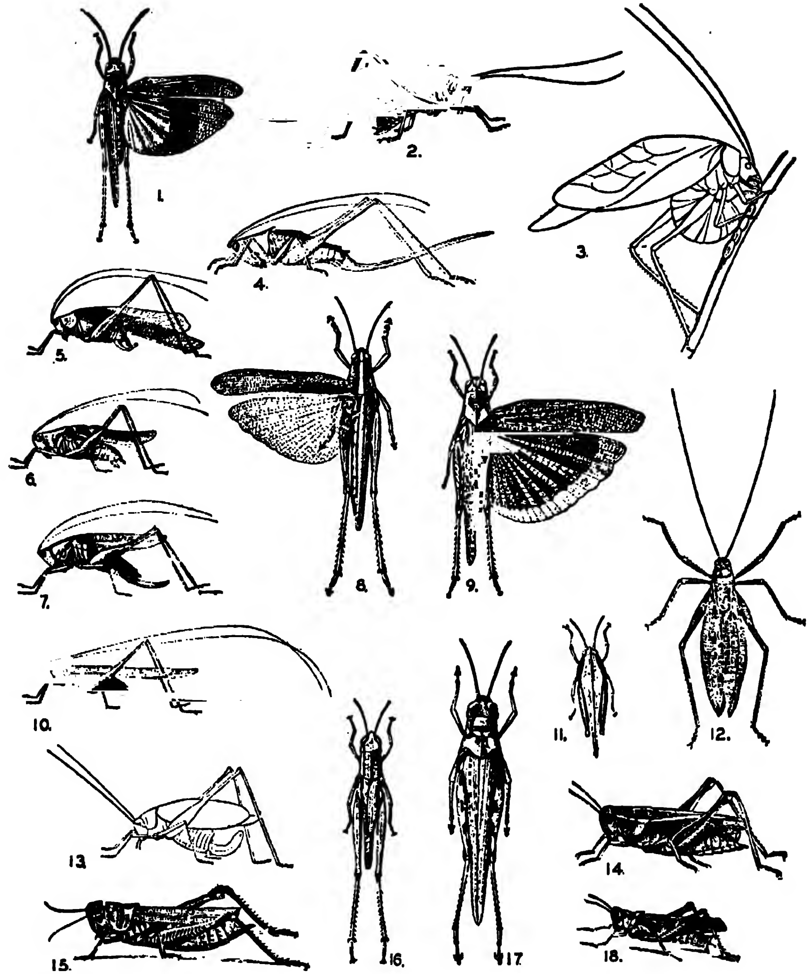


Plate IX. Long-horned and short-horned grasshoppers. 1. Sand-colored grasshopper (*Spharagemon bolli*), after Lugger; 2. Angle-winged cricket; 3. Angle-winged cricket depositing eggs; 4. *Xiphidium strictum;* 5. Forked katydid (*Scudderia furcata*), after Lugger; 6. Meadow grasshopper (*Orchelium vulgare*), male and 7. female; 8. *Schiztocera alutacea;* 9. *Dissoteria carolina;* 10. *Xiphidium attenuatum*, after Lugger; 11. Grouse locust (*Tettigidea lateralis*), after Lugger; 12. Common katydid (*Cyrtophillus perspicatus*), after Lugger; 13. Round-winged katydid (*Amblycorypha rotunda*); 14. Two-striped grasshopper (*Melanoplus vittatus*); 15. *Melanoplus differentialis*, after Riley; 16. Short-winged grasshopper; 17. Lesser grasshopper; 18 Red-legged grasshopper (*Melanoplus femur rubrum*). Courtesy Ill. State Lab. Nat. Hist.

foliage. It is easily collected by placing open umbrellas on the ground and then violently shaking or beating the tree. Some tropical walking-sticks attain an enormous size, while others have leaf-like wings.

The roaches (*Blattidae*) include an objectionable group containing the household species, all of which have been introduced from other lands. The croton bug or German cockroach is the common brownish household pest which, with the Oriental roach, is now a cosmopolitan species. A large, almost black, hard-shelled roach frequently invades cellars through drains.

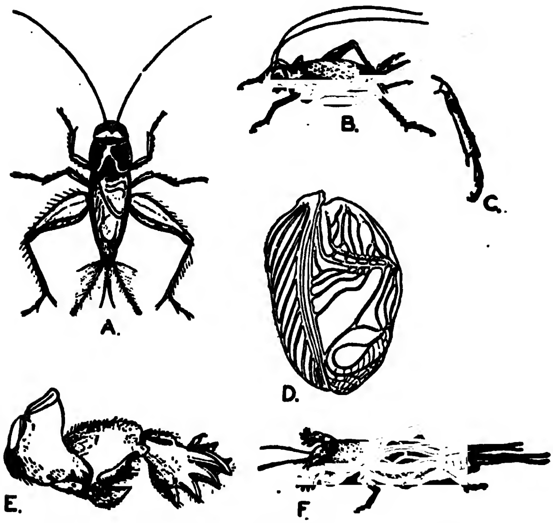


FIG. 79. Crickets (*Gryllidae*). A. House cricket (*Gryllus domesticus*); B. Female *Gryllus;* C. Front leg showing ear; D. Cricket's musical apparatus; E. Front leg of mole cricket; F. Mole cricket (*Gryllotalpa borealis*). B, C, D, F. after Lutz, *Fieldbook of Insects*, courtesy G. P. Putnam's Sons; A. after Herrick, E. after Sedgwick, from Hegner, *Invertebrate Zoology.*

The American cockroach is a very large, broad species that has been brought from the tropics in fruits.

The native roach or wood roach is a flat, woodland species which is sometimes attracted to lights at night. It is not a household pest. All roaches are runners and flee from light. They feed upon dry animal and vegetable matter as a rule. Many tropical species are excellent fliers. Roaches deposit their eggs in oblong cases which they sometimes carry about with them until hatching time (Fig. 80).

The praying mantis (Fig. 83) (*Mantidae*) is the only really beneficial member of the Orthoptera. It is more common in tropical and subtropical regions, although the large Japanese species is becoming generally distributed in temperate regions. The mantis with its spiny, grasping front legs is a destroyer of

caterpillars, grasshoppers, and other insects. The eggs are deposited in silken cases (oöthecae) which are attached to the stems of plants.

Isoptera (equal wings). Among the most interesting but most destructive of insects are the termites or white ants. In the spring, great swarms of winged, ant-like insects appear in cellars, on porches, and occasionally inside houses. After a brief sojourn which brings despair to property owners, the insects suddenly disappear, leaving only a myriad of wings as a record of their visit.

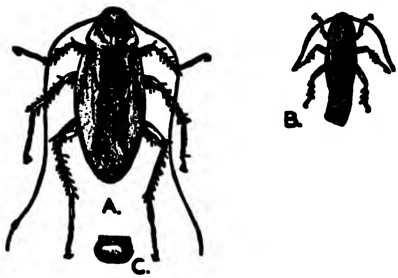


FIG. 80. Roaches (*Blattidae*). A. *Periplaneta americana;* B. Croton bug (*Blattella germanica*); C. Egg capsule. After Lutz, *Fieldbook of Insects*, courtesy G. P. Putnam's Sons.

In the hidden recesses of wooden building supports, furniture, cabinets, flooring, unused books, and even clothing, the termites establish their gigantic colonies numbering thousands of individuals. In these places they devour the inner parts of the material, leaving only the thin outer wall or shell which even in hard woods can be punctured with the finger. So concealed are the activities of the termites that tremendous damage is done before their presence is discovered. The spring swarms indicate the presence of colonies, and it is then time to seek their hideouts and destroy them before they do an irreparable damage. Trees fall, buildings collapse, and other objects fall to pieces as the result of the depredations of these insects.

FIG. 81. A wingless grasshopper or cave cricket (*Ceuthophilus*). After Lutz, *Fieldbook of Insects*, courtesy G. P. Putnam's Sons.

While termites are extremely abundant in tropical regions, there are fifty-five species in the United States. Tropical forms are imported in materials, especially timber, brought from tropical regions. Termites reach the timber in buildings sometimes through subterranean channels, while others are in the wood used in construction.

Termites are primitive insects more closely related to the

roaches than they are to the ants with which they are frequently confused. While their food consists mainly of wood, they will devour almost anything of an organic nature, such as paper, clothing, and even straw hats.

Termites are blind, and they usually construct tunnels or covered runways to shield themselves from the light when they are working on the surface of objects. In South America and Africa they make huge nests which are sometimes twenty feet high. The nest is made of chewed material and is similar in texture to papier maché. When they have runways on trees, they are always canopied; and one species which is abundant in the Amazon country builds rain-shedding galleries on the trunks of mora trees.

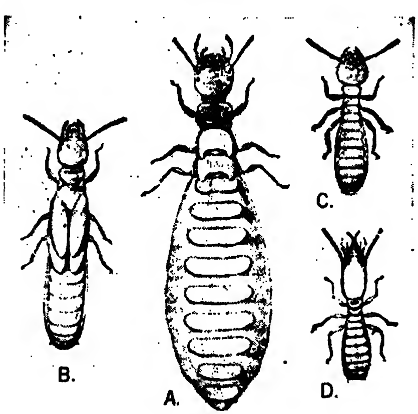


FIG. 82. Termites or white ants. A. Queen; B. Young winged female; C. Worker; D. Soldier. After Marlatt, courtesy U. S. Dept. Agric.

The termites have one of the most remarkable social organizations ever conceived, being superior to those of ants and bees which are much more complex from the standpoint of anatomical makeup. In the colony there are four principal kinds of individuals (Fig. 82). These types are known as castes, and there are modifications of the chief castes. The kinds are: (1) *workers*, which are by far the most numerous individuals in the colony. While the worker of a bee or ant is always a female, the worker termite may be either sex, although the sexual organs remain undeveloped. The workers make the nest, provide food, feed and care for the young and the royal pair, and attend to other duties in the colony. There is sometimes considerable variation in the worker caste. (2) The *soldiers* may be either male or female also; but they too have undeveloped sex organs. The head of the soldier is extremely large, and it bears a pair of well-developed jaws. The soldiers are the defenders of the colony. (3) The *winged males* and (4) *females*, which constitute the swarms already referred to, are sexually mature. The swarm represents the nuptial flight during which mating takes place. After mating the wings break off along a

special suture provided for that purpose, and the pair enters a burrow to begin a new colony. This mating pair are the king and queen. After establishing themselves, the queen becomes enormously large, being many times larger than other individuals. The queen may live for many years, and she is capable of laying eggs at the rate of sixty per minute for long periods of time. The

FIG. 83. The praying mantis. Courtesy U. S. Dept. Agric.

king and queen are fed by workers. The greatly exaggerated body of the queen makes it impossible for her to move about.

Associated with termites are several other animals, mostly insects, which have various relationships with their hosts, mostly symbiotic and commensal. These are called termitophiles. The termites sometimes carry the guests about.

Termites may be distinguished from ants by their lack of the slender petiole or waist that joins the thorax and the abdomen. In other words, the termites are broad-waisted while the ants are narrow-waisted. The antennae of termites are like tiny strings of roundish beads, and a pair of abbreviated cerci are usually present on the abdomen.

The termites undergo a gradual metamorphosis (paurometabolous).

Plecoptera (plaited wings). This order includes the stoneflies which were discussed in the chapter dealing with animals of the streams. The stoneflies have four wings, the anterior being smaller than the hind wings which are folded in plaits when at rest. The metamorphosis is direct; the antennae are filiform; the mouth parts are adapted to chewing; the abdomen with a pair of jointed bristle-like appendages (cerci); the adults have tracheal gills (see Water insects). The larvae, naiads, or nymphs are thysanuriform and aquatic, living in swift water. The adults are aerial and nocturnal. They are attracted to lights at night and rest by day on the vegetation along the stream (Fig. 42).

Fig. 84. The black peach aphis (Homoptera-*Aphididae*). From Farmer's Bull. 1128, courtesy U. S. Dept. Agric.

Ephemeroptera or Ephemerida (a May fly). The adults are aerial insects with four delicate membranous wings which are triangular in outline. The front wings are much the larger. The mouth parts are vestigial, and the abdomen usually carries two or three long thread-like appendages. In some species the eyes are divided. The larvae, nymphs, or naiads are all aquatic and live in ponds or streams according to the species. The metamorphosis is complete. The May flies are discussed under stream animals (Fig. 42).

Odonata (a tooth). These are the dragon flies and damsel flies. The former are sometimes called "devil's darning needles," "mosquito hawks," "snake feeders," "snake doctors," or "hell-borers."

The dragon flies have prominent eyes which are convergent or almost touching each other on the top of the head. They have four membranous wings which are held horizontally when at rest. The hind wings are broader at their bases than are the fore

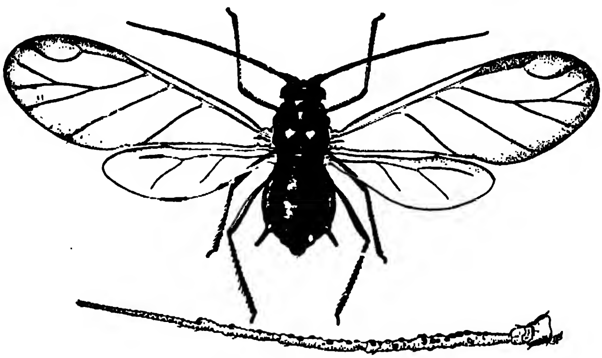


Fig. 85. The black peach aphis. Antennae enlarged to show sensitive pits. From Farmer's Bull. 1128, courtesy U. S. Dept. Agric.

wings. The mouth parts are adapted to chewing, and the legs fold to form a "basket" in which captured food is carried.

There are two principal families of the dragon flies —*Libellulidae*, to which most of the commoner species belong; and *Aeschnidae*, which includes the largest dragon flies (Fig. 31).

The damsel flies (Fig. 32) are delicate insects resembling dragon flies but usually much smaller. The four wings are nearly equal in size and shape. The eyes are globular, opaque, and divergent. There are two principal families of damsel flies. *Agrionidae*, the broad-winged damsel flies, include the blue, purple, and metallic species such as the green-bodied, smoky-winged damsel flies commonly seen along woodland streams. *Coenagrionidae* includes the narrow-winged, less conspicuously colored species. The general structure, life history, and habits are similar to dragon flies. All are aquatic in the larval or nymphal stages. Many weird superstitions resulting in a general fear of these magnificent and beneficial insects are entirely unjustified. The bases of speciation are wing venation and external genitalia. Needham's *Handbook of Dragonflies* is probably the most complete available work for

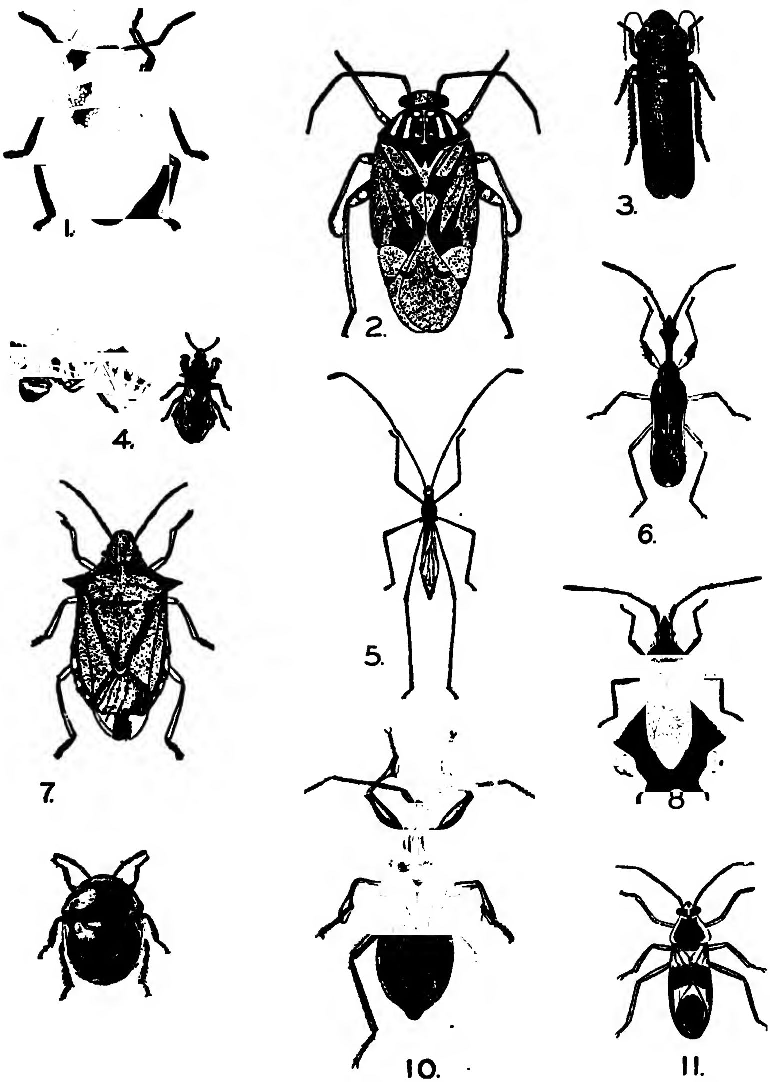


Plate X. Bugs (Hemiptera). 1. Stink bug, *Stiretrus anchorago* (*Pentatomidae*), after Riley; 2. Tarnished plant bug, *Lygus pratensis* (*Lygaeidae*); 3. Plant bug, *Acanthoceros galeator;* 4. Ambush bug, *Phymata fasciata* (*Phymatidae*), after Riley; 5. Stilt bug or red-legged bug, *Jalysus spinosus* (*Neididae*), after Lugger; 6. *Myodocha serripes* (*Lygaeidae*); 7. Stink bug, *Euschistis variolarius* (*Pentatomidae*), from Hegner, *Invertebrate Zoology;* 8. Leaf-footed bug, *Leptoglossus oppositus* (*Reduviidae*), after Chittenden; 9. Negro bug, *Thyreocoris pulicarius* (*Pentatomidae*); 10. Black pirate, *Melanolestes picipes* (*Reduviidae*); 11. Large milkweed bug, *Lygaeus kalmii* (*Lygaeidae*). All, except 8, courtesy Ill. State Lab. Nat. Hist.

determining species of nymphs. *The Field Book of Insects* by Lutz and *The Insect Book* by Howard are probably the most available for the identification of adults.

Psocoptera or Corrodentia (gnawing teeth). The book lice are very small, whitish, soft-bodied insects found among old papers and books in damp places. They have four membranous wings, the front ones being the larger. The mouth parts are formed for chewing. The book lice undergo a gradual metamorphosis.

Fig. 86. The woolly aphis on an apple twig (Homoptera-*Aphididae*). From Farmer's Bull. 1128, courtesy U. S. Dept. Agric.

Neuroptera (nerve-winged). The neuropterous insects have two pairs of large, membranous wings. The mouth parts are mandibulate, and the antennae are long. Among the nerve-winged insects are to be found a few remarkable forms such as the dobson fly (*Corydalidae*) (Fig. 43), ant lion (*Myrmeleonidae*) (Fig. 91), alder flies (*Sialidae*) (Fig. 29), and lace-wing (*Chrysopidae*) (Fig. 68). The dobson and alder flies are discussed under Aquatic animals.

In sandy regions one frequently sees small, conical pits excavated in the dry and finer sand. Usually these pits are in the shelter of plants or buildings where they are protected from the rain; but not infrequently they may be seen in open places. These excavations are made by the "ant lion," a very predaceous larva that remains concealed under the sand in the bottom of the pit (Fig. 91) waiting for some luckless ant or other insect to descend into it. The unwary insect that does enter the pit seldom leaves

it. The steep sides of loose sand preclude escape; for when the unfortunate victim attempts to crawl out, the loose sand slides beneath it, and to make escape impossible the larva begins to throw sand violently from the bottom causing a veritable land slide which carries the entrapped creature to the bottom where it is immediately seized by the powerful jaws of its enemy and quickly dragged out of sight.

Fig. 87. The saliva nest of the spittle insect or froghopper (*Cercopidae*). Courtesy Bur. Ent., U. S. Dept. Agric.

When mature the larva pupates within a round cocoon which looks like a small marble of sand. The adult is a gauzy-winged, aerial insect that, in a way, resembles a damsel fly. It is easily distinguished by its short but prominent antennae which are lacking in damsel flies, and its more or less uncertain flight.

The lace-wing (*Chrysopa*) (Fig. 68) is a very common neuropterous insect attracted to lights at night or it may be taken in great numbers by sweeping the low vegetation in summer. It has transparent, opalescent, many-veined wings, golden eyes, and a nile-green body which has a characteristic and rather offensive odor. Once handled, it will never be forgotten. The remarkable habit of placing the eggs on hair-like stalks has already been described.

Mallophaga (wool eater). The biting bird lice are very small, parasitic, wingless, chewing insects usually found on birds but occasionally infesting other animals.

Thysanoptera (fringed wing). The thrips are small, dark, elongated insects with tapering abdomens which they raise menacingly as though they possessed stings. They are found in flowers, and the breaking apart of daisy heads usually reveals many of them. Winged species frequently appear on one's hand, coming apparently from nowhere. The tarsi are swollen and bladder-like, and formerly the insects were called *Physopoda*, which means

balloon-footed. Thrips are responsible for considerable damage to crops, especially to onions on which their piercing or sucking mouth parts form black spots. This seems to be a feminine group since no males have ever been found.

Anoplura or Parasita (parasites). The true lice include body lice, head lice, crab lice, and other species parasitic on animals. They are degenerate, minute insects lacking wings but having bodies modified for clinging to their hosts (Fig. 5).

Dermaptera or Euplexoptera (well-folded wings). The earwigs are beetle-like insects which are readily identified by the prominent

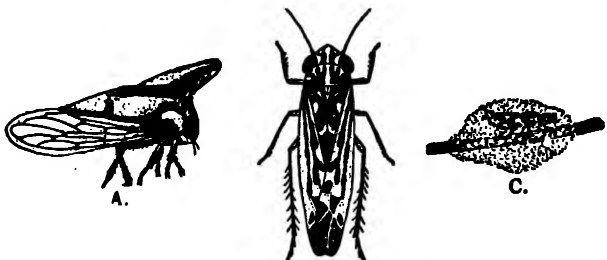


FIG. 88. Homoptera. A. Tree-hopper (*Membracidae*); B. Leaf-hopper (*Cicadellidae*); C. Spittle insect (*Cercopidae*). From Hegner, *Invertebrate Zoology.*

pincers or forceps on the posterior end of the body and by their short, horny wing covers. The earwigs are mostly southern, where they may be a serious menace to growing plants. Some of them eat other insects, while still others feed upon decaying material. The eggs are laid in the soil, and the mother stands guard over them until they are hatched. The metamorphosis is gradual, the young being called nymphs (Fig. 78).

Mecoptera (long-winged). The scorpion flies are wasp-like insects which are common in most regions. The name is applied to the order because certain males have an upturned, swollen tip on the abdomen. The insects have four long, narrow, membranous wings with numerous cross veins. The antennae are long and slender, and the mouth parts are adapted to chewing. The larvae are caterpillar-like, but these may be distinguished from the Lepidoptera by their eight pairs of prolegs. The pupae have the wing cases and leg cases free from the sides of the body. The adults may be taken by sweeping the dense grasses in damp places. They bear a superficial resemblance to certain wasps (Fig. 90).

Trichoptera (hairy-winged). The caddis flies are moth-like insects with extremely long antennae and four very hairy wings which are held along the body in a sloping position on the sides when at rest. The eggs are laid in the water in strings or masses under stones. The larvae are worm-like, and these construct curious cases of sticks, stems, leaves, pebbles, or sand in which they live and pupate while in the water. There are many species of caddis flies, and each kind builds its own characteristic case which is carried about. During the day the adults rest upon the foliage along a stream or about a pond. The metamorphosis is complete. The caddis flies are discussed under Water life.

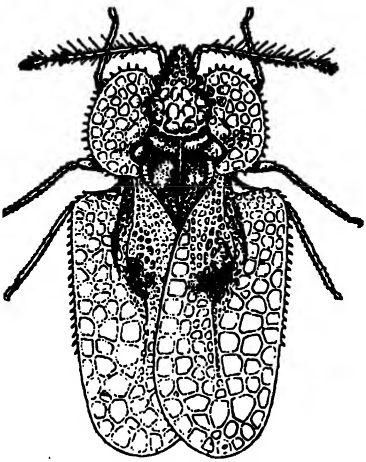


FIG. 89. A lace-bug, *Corythuca* (*Tingidae*). Courtesy Bur. Ent., U. S. Dept. Agric.

Some cases of caddis flies are shown in Plate I. An adult is shown in Fig. 42.

Siphonaptera. The fleas constitute a small, well-defined order; and they have no close relatives. All of them are wingless, and all of them, in their adult stages, are external parasites on warm-blooded vertebrates. The body of the flea is hard, laterally flattened, and covered with backward-pointing hairs and stout spines. The legs are long and adapted for jumping. The coxal segment is usually the most prominent one. Many of the fleas are totally blind, while some of them have simple eyes. The mouth parts are adapted for piercing and sucking, and the three thoracic segments are separate and distinct. The antennae are very short. The fleas undergo a complete metamorphosis. The eggs hatch into twelve-segmented, slender, cylindrical, legless and eyeless, whitish, maggot-like larvae with chewing mouth parts. The larva pupates within a cocoon. The order includes the well-known fleas of dogs and cats which are frequently of annoyance to humans. The chigger flea or chiggoe of the South, which penetrates the skin of humans and develops a large, painful swelling, especially on the feet and under the toe nails, belongs to this order, as does

the sticktight flea which infests chickens and other domestic fowl. Fleas are the carriers of the dreaded bubonic plague. Rats, mice, rabbits, squirrels, and many other animals may have fleas. The human flea (*Pulex irritans*) is also common to domestic animals (Fig. 5).

Lepidoptera (scaly-winged). The moths and butterflies, because of their brilliancy, constitute the most picturesque of all insect groups. Next to the beetles it is the largest order of insects in the world. The broadly expanded, non-collapsible wings which are

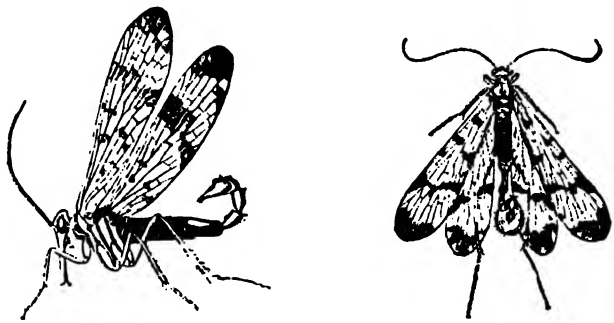


FIG. 90. Scorpion flies (Mecoptera). a. *Bittacus*, lateral view; b. *Panorpa*, dorsal view. From Kellogg, *American Insects*, courtesy Henry Holt and Co.

covered with dense, flattened hairs or scales, most of which are brightly colored, make the members of the group easy to identify, as far as the order is concerned. The powdery material which covers the upper and under surfaces of the wings in both the moths (*Heterocera*) and the butterflies (*Rhopalocera*) is usually a myriad of overlapping, sac-like scales which give the order its name. Under magnification the scales are seen to represent a wide diversity of form. In the lower members of the order the scales are irregularly distributed over the wings, but in the higher individuals the scales are arranged in perfect rows.

The scales serve to strengthen the delicate membranous wings which are almost transparent when the scales are rubbed off. The broad wings of most species preclude rapid flight; and those which do fly swiftly such as the hawk moths or sphinxes have narrow wings. The scales on the wings are modified hairs, and they are specializations of hairs similar to those on the wings of the caddis flies, to which the Lepidoptera are related.

While most moths and butterflies are born and reared on land,

there are a few which undergo a part of their life history in water. As a group, the Lepidoptera must be considered as harmful. In the adult stage, both the moths and butterflies perform a valuable service in cross-pollinating flowers. This is especially true of the moths which are the chief pollinating agents in night-blooming flowers. However, the caterpillars of practically all species are plant eaters, and some of them are among our most destructive insects. The corn worm, the bagworm, the cabbage and tomato worms, the European corn borer, army worm, tent caterpillar, and the cutworms are all Lepidopterous larvae. These, with scores of others, constitute a constant menace to growing plants. The gypsy moth, brown-tailed moth, the tussock moth, and numerous others are very destructive to shade trees.

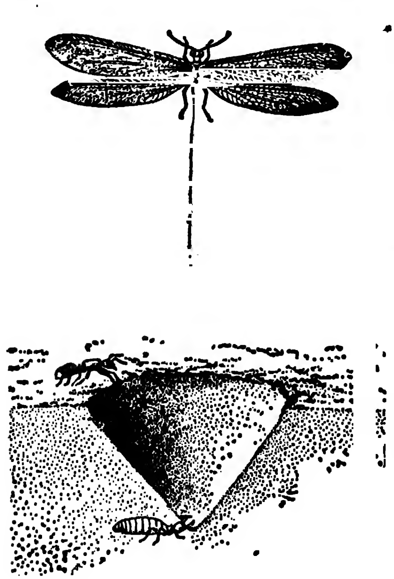


Fig. 91. The ant lion (adult) and larva in its pit. (Neuroptera). From Lutz, *Fieldbook of Insects*, courtesy G. P. Putnam's Sons.

However, there are a few beneficial kinds such as the slug-like larvae of the *Lycaenidae*, a family of small butterflies known as the blues and the coppers. The larvae of these are flattened, slug-like, and carnivorous. They prey upon plant lice. But of the thousands of species of moths and butterflies to be found in the United States, these are the only ones that are really beneficial. Of course, there are some which feed upon weeds; and these undoubtedly help to keep some noxious plant pests in check; in this capacity they may be considered as beneficial.

Butterflies may be distinguished from moths by rather obvious differences. The antennae or feelers of butterflies are thread-like and always knobbed or clubbed at their distal ends. The antennae of moths may also be thread-like, but they are never knobbed or clubbed. In moths the antennae are usually feathery or plumose; and, as a rule, the male antennae are much more plumose than those of the female. The bodies of moths are usually larger in

proportion to the wing spread, and they are much more hairy than those of butterflies. The skippers (*Hesperiidae*) are exceptions to this difference. When at rest, the butterflies hold their wings erect with the upper surfaces opposed, while the moths hold their wings horizontally extended or they allow them to rest on the back.

Butterflies are diurnal; that is, they are active during daylight hours; while most moths are nocturnal in their habits, although there are numerous exceptions. As a rule, moths spin cocoons of silk in which the caterpillars pupate, although some moths such as the tomato worm moth (Sphinxes) pupate in the ground, and they therefore have no cocoons, the pupa being naked. The butterflies do not spin cocoons but pupate in naked, angular chrysalids (Fig. 71).

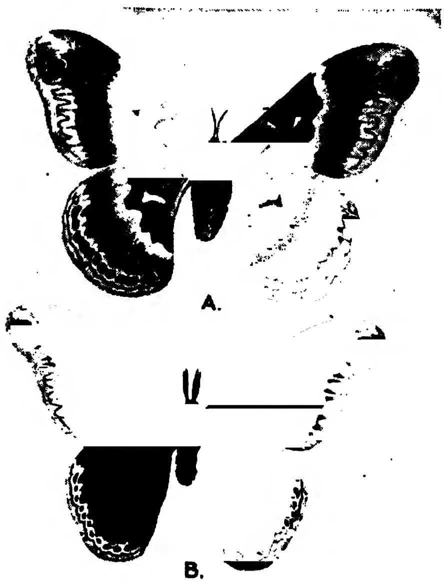


FIG. 92. The promethea moth, *Callosamia promethea* (*Saturniidae*). A. Female; B. Male.

All of the Lepidoptera undergo a complete metamorphosis, the eggs hatching into worm-like caterpillars which eat voraciously and build up reserves of fatty tissues to nourish them while in the pupal stage. The caterpillars are usually equipped with well-developed mouth parts and functional eyes. They are sometimes formidable-looking creatures (especially the larvae of the royal walnut moth, the puss moth, and the Cecropia), with long hairs, spines, and eye spots; but there are only a few common kinds which are unsafe to handle. Among these are the larvae of the Io moth, the oak slug caterpillar, the saddle-back caterpillar (*Sibine stimulea*) (Fig. 70). There is some evidence to show that the larvae of the "woolly bear" moths (*Arctiidae*) are also irritating. On these caterpillars there are brittle, penetrating hairs

which on some species, such as the *Io* and saddleback caterpillars, are poisonous. Such wicked and formidable-looking caterpillars as the hickory horned devil (Fig. 94), the puss moth larva (Fig. 19), and the Cecropia caterpillar (Fig. 73 F) are perfectly harmless and can be handled with impunity. Caterpillars shed their skins from time to time as they grow larger, and when they mature, they pupate. The imago or adult develops within the pupa. The adult moth or butterfly is a short-lived creature, as a rule; and its sole purpose is usually to mate and reproduce. Many of them such as the Cecropia have no well-developed mouth parts and therefore never feed. There are many others, however, which do have well-developed mouth parts. In most cases of moths and butterflies the mouth consists of a coiled sucking tube through which nectar is drawn from flowers (Fig. 111).

FIG. 93. The polyphemus moth, *Telea polyphemus* (*Saturniidae*).

In general, the moths and butterflies winter in the pupal stage, although the "woolly bear" caterpillar frequently passes the winter in the larval stage. It may be found under stones and other objects on the ground, either naked or encased in a flimsy cocoon during the cold months. The woolly bear is the chubby brown-and-black caterpillar that one frequently sees hurrying across the road late in the fall as though it were afraid that cold weather would overtake it before it reached a haven of safety. The mourning cloak butterfly (*Aglais antiopa*) (Fig. 122) winters in the adult stage, hiding in some protected crevice during bad weather. It is not uncommon to see

FIG. 94. The imperial moth, *Basilona imperialis* (*Saturniidae*). After Felt, courtesy Ill. State Lab. Nat. Hist.

the mourning cloak (also called the Camberwell beauty) flying about when warmer breaks occur in winter months.

There are frequently vast differences in color between males and females among both moths and butterflies. In some kinds such as the tussock and bagworm moths, the females are wingless. Sometimes these differences are so great that the sexes may be mistaken for different species (Fig. 55). In the species that have several broods in a season, there are usually distinct differences between the generations; and these, too, may be taken for different species.

There are so many kinds of moths and butterflies that a complete discussion of them would be too voluminous for inclusion here, and the student is referred to the literature appended to this chapter for further information regarding them.

There are five common families of butterflies. The skippers (*Hesperiidae*) (Fig. 115) are quite different from the others in that they have thickset bodies similar to those of some moths. Their antennae are set wide apart, and they are recurved or hooked at their tips. The caterpillars of the skippers have a constriction, resembling a neck, back of the head.

The swallow tails (*Papilionidae*) (Fig. 116) are the largest of our native butterflies. They include such very common species as the black swallow tail which feeds upon wild carrot (*Papilio polyxenes*), the tiger swallow tail (*Papilio turnus*), the dutchman's pipe vine swallow tail (*Papilio philenor*), the spice bush swallow tail (*Papilio troilus*), and the beautiful *Parnassius* which is found only at extremely high elevations. Incidentally, the members of the latter genus are found above ten thousand feet on practically all mountains in the world, and the various kinds from the Orient, the Alps, the Andes, and the Rocky Mountains are quite similar in appearance to the amateur.

The family *Pieridae* includes the cabbage butterflies (Fig. 123) and the sulphurs which are shaped like the cabbage butterfly but with a beautiful yellow or orange coloration. They range in size from one and one-half to two and one-half inches.

The *Nymphalidae* includes such common butterflies as the monarch (Fig. 15), the mourning cloak (Fig. 122), the viceroy (Fig. 15), the wood nymphs (Fig. 125), the red admiral (Fig. 121), and the silver spots (Figs. 117–118). They attain a maximum size of not over four inches. The family is sometimes referred to as the

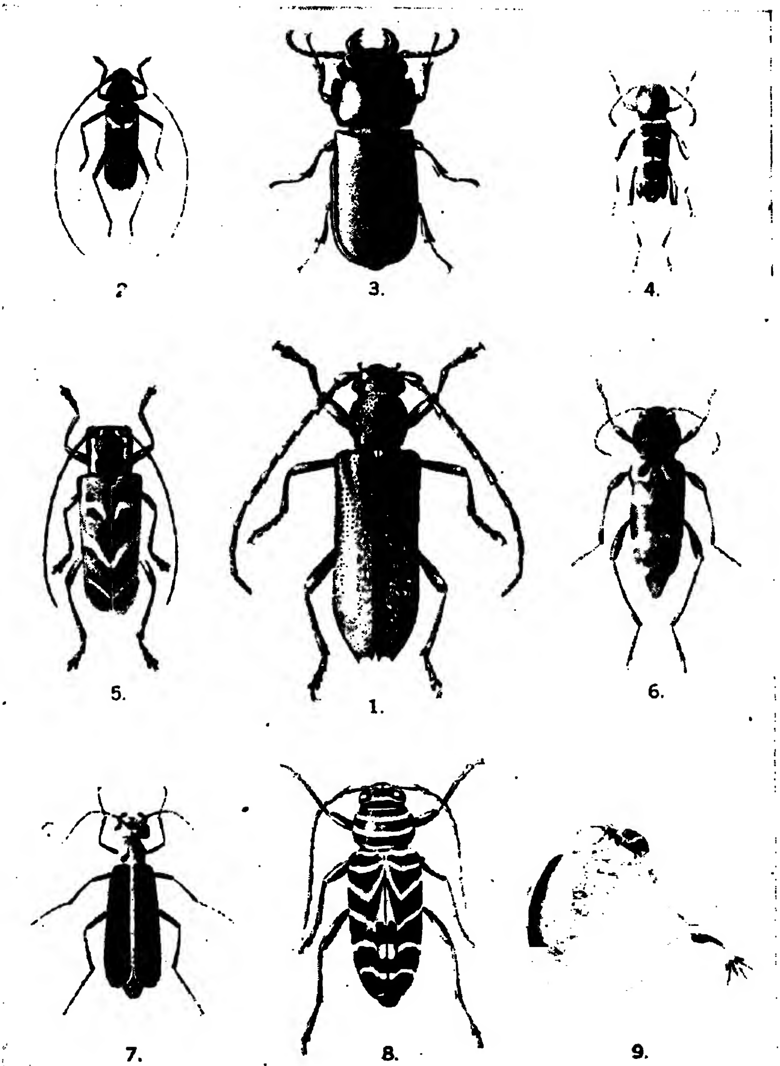


PLATE XI. Some common beetles. 1. Twig pruner (*Elaphidion villosum*); 2. Banded hickory borer (*Chion cinctus*); 3. *Parandra brunnea*, after Snyder; 4. *Neoclytus sp.*; 5. Elm borer (*Saperda tridentata*); 6. *Xylotrechus colonus;* 7. *Epicauta vittata;* 8. *Cyllene robiniae*, after Hopkins; 9. Chestnut weevil, after Brooks. 1., 2., 4., 5., 6. courtesy Ill. State Lab. Nat. Hist.; 3., 7., 8., 9. courtesy Bur. Ent., U. S. Dept. Agric.

four-footed or brush-footed butterflies because in the adults the front legs have degenerated so that they do not appear as legs; and only four legs are functional.

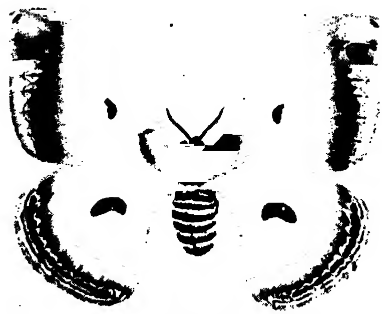


FIG. 95. The cecropia moth, *Samia cecropia* (*Saturniidae*).

The *Lycaenidae* includes the hairstreaks, the coppers, and the blues. They are mostly small, ranging from one-half to one and one-half inches. Brown is the predominant color in this group, although some of them are blue. The caterpillars are slug-like; and one carnivorous species which resembles a monkey's skull feeds upon the woolly aphis. Some common species are shown in Fig. 124.

Butterflies are found wherever flowers grow. Some species keep pretty well in the woods, but most of them are in the open, visiting the highly colored flowers on sunny days. At night and during rains they rest, usually on the undersides of leaves. Sometimes they collect in numbers about mud puddles, and some species congregate in thousands, probably for mating purposes. The writer once saw thousands of heliconid butterflies assembling on a large bindweed in the Amazonian jungles. It was remarkable that they could find a common meeting place in the dense forests where vision is hardly possible beyond fifty or a hundred feet and where there is not an abundance of light. However, these butterflies, species of which are to be found in the United States, have tufts of glandular hairs on the sides of their abdomens. These emit a "perfume" which is recognized by others of their kind, and it is probable that they are guided together by the sense of smell.

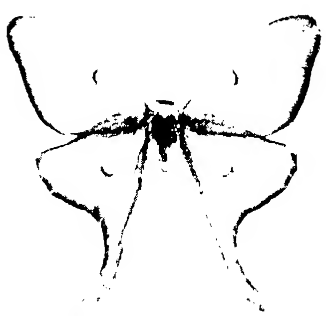


FIG. 96. The luna moth, *Actias luna* (*Saturniidae*).

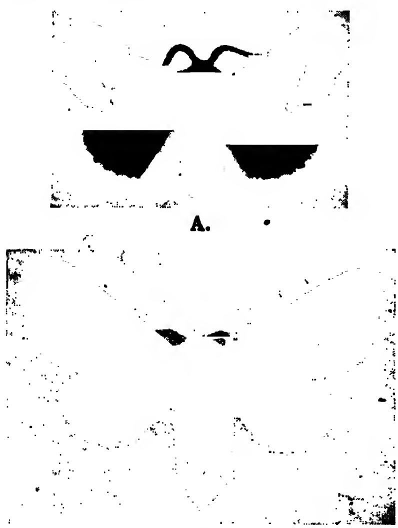
Some of our native butterflies, notably the monarch or milkweed

butterfly (*Danais*), congregate in great numbers and migrate in a manner similar to birds. The writer once collected this species in South America.

There are twenty-eight families of moths, many of which are quite common. They range from tiny clothes moths to the huge

FIG. 97. Leopard moth, *Zeuzera pyrina* (*Cossidae*). Courtesy Bur. Ent., U. S. Dept. Agric.

emperor or Cecropia which is very common in the spring. In South America and in Africa there are moths with a wing spread of nine inches.



A.

B.

FIG. 98. Adult moths of the apple tent caterpillar, *Malacosoma americana* (*Liparidae*). A. Male; B. Female. After Quaintance, Farmer's Bull. 662, U. S. Dept. Agric.

Some of the common families are: the clothes moth (*Tineidae*); the leaf rollers (*Tortricidae*); the snout moths (*Pyralidae*) of which the European corn borer is an example; the hawk moths or sphinxes (*Sphingidae*) to which thysbe (Fig. 103), the tomato worm moth (Fig. 105), the grape vine moth (*Amphion nessus*) (Fig. 108), and numerous others belong; the tussock moths (*Lymantriidae*) (Fig. 108); the tiger moths (*Arctiidae*) to which the hickory tiger moth (Fig. 108) belongs; the royal moths (*Citheroniidae*) including the royal walnut moth (Fig. 109); the clear-winged moths (*Aegeriidae* or *Sesiidae*) which includes the peach borer (Fig. 110); the measuring worm or canker worm moths (*Geometridae*); the prom-

inents (*Nadata—Notodontidae*) (Fig. 108); the cutworm moths (*Arctiidae*), the most destructive family and the one to which the corn ear worm belongs; the carpenter moths (*Cossidae*) which includes the leopard moth (Fig. 97), the larva of which bores into the stems of twigs; the tent caterpillar (*Lasiocampidae*) including the apple tent caterpillar (Fig. 99); the bagworm moths (*Psychidae*) (Fig. 100); the flannel moths (*Megalopygidae*); and the giant silkworm moths (*Saturniidae*). To the last-named family belong some of our largest, most beautiful, and most colorful species, such as *Polyphemus* (Fig. 93), *Cecropia* (Fig. 95), *Promethea* (Fig. 92), and *Luna* or pale empress of the night (Fig. 96).

Fig. 99. The apple tent caterpillar. Courtesy U. S. Dept. Agric.

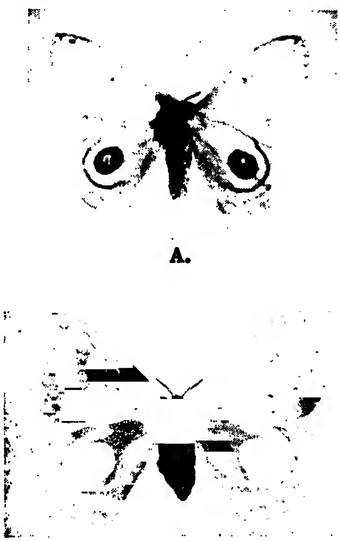
Coleoptera (sheath wing). The beetles are the most abundant of the insects in point of species, there being about 70,000 species in North America alone. Furthermore, they exhibit a more extensive adaptive radiation than any other group. Numerous species, such as ladybugs, potato beetles, asparagus beetles, flea beetles, and May beetles ("June bugs") are found in gardens. The whirligigs live on the surface of ponds and streams, while there are a great many other kinds, including the predaceous diving beetles and the water scavengers, which live in the water. Carpet beetles (*Dermestidae*) and meal-infesting forms (*Tenebrio molitor*, *Tribolium confusum*, *Sitodrepa panicea*) are common household pests. One form is parasitic on the beaver, while hun-

Fig. 100. Cases of the bag worm moth, *Thyridopteryx ephemeraeformis* (*Psychidae*). Courtesy Bur. Ent., U. S. Dept. Agric.

dreds of species are to be found on the ground, in plants, and in logs. In fact, one can find beetles everywhere, day or night. They range in size from almost microscopic forms to the gigantic hercules and goliath beetles of South America and Africa.

While most beetles have hard and brittle outer wings (sheath wings or elytra) and exoskeletons, there are numerous forms such as the firefly or lightning bug (*Lampyridae*), the blister beetles (*Meloidae*), and some of the short-winged carrion forms (*Staphylinidae*) which are comparatively soft.

Beetles can easily be distinguished from other insects by the fact that the front or outer wings (elytra) meet so as to form a straight line down the middle of the back. This is also true of the earwigs, only the pincer-like structures on the end of the abdomen in the latter make them readily distinguishable. The antennae are quite variable but characteristic for families.



A.

B.

FIG. 101. The io moth, *Automeris io* (*Saturniidae*). A. Male; B. Female.

Some of our most interesting larvae are the young of the beetles. Among these are the glow worms, which are the wingless females of certain species of fireflies; the water penny, the most curious beetle larva known, which is found attached to stones in streams and which is the young of the brook beetle; the wireworms which grow up to be click or snapping beetles; the "chestnut worm" which grows up to be a small, brownish, snout beetle; the "white grubs" in the soil of fields and gardens which are young June bugs; the water tiger, which is the young of the diving beetle; the aquatic *Helodidae;* and numerous others.

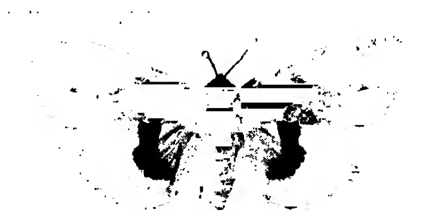


FIG. 102. The rose underwing, *Catocala cara* (*Noctuidae*).

On the whole the beetles are destructive, but there are some very valuable kinds to be found among them.

There are numerous families of beetles, and there is a wide variation of habits within each family. Space permits the mention of only the most common and spectacular forms. The student is referred to the references at the end of the chapter for further details.

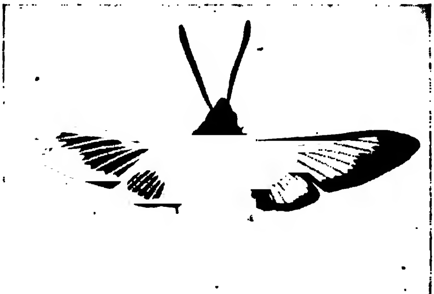


FIG. 103. The hummingbird moth, *Hemaris thysbe* (*Sphingidae*).

The ground beetles (family *Carabidae*) are, as a rule, beneficial. They are the black or brownish long-legged forms found under objects on the ground. They are active at night, and they are usually predaceous, feeding on other insects. While most of them are inconspicuous, there are three rather common highly colored species which warrant discussion.

The fiery hunter (*Calosoma calidum*) (Fig. 130) is a rather large beetle with rows of reddish-gold pits on the outer wings. The "lion beetle" (*Calosoma scrutator*) is a large green ground beetle with a purplish border on the elytra. Both of these are destroyers of caterpillars. The bombardier beetle (*Brachinus fumans*) is a medium-sized beetle with bluish elytra and reddish head and thorax. It is the originator of gas warfare; and when disturbed it violently ejects a spray of noxious gas to discourage its captor. It is found under objects on the ground in both woods and open fields.

FIG. 104. The waved sphinx, *Ceratomia undulosa* (*Sphingidae*).

The tiger beetles (*Cicindelidae*) (Fig. 129) are the shining green forms that abound on hot sands and stones in summer. As one walks along, the tiger beetles fly a short distance ahead and alight, always turning to face the approacher. They are predaceous; and being excellent fliers and runners, they overtake their victims and pounce upon them in tiger-like fashion.

The longhorns (*Cerambycidae*) comprise many species, most of which are wood borers. The antennae are very long, being frequently several times the body length. Many of them produce a singing noise when caught. Among the commoner forms are the

FIG. 105. Tomato worm hawk moth, *Phlegethontius carolina* (*Sphingidae*).

milkweed beetle (*Tetraopes tetraophthalmus*), which is a small, reddish beetle with black spots on the elytra and thorax; and our largest beetle (*Prionus laticollis*) (Plate XII, Fig. 14), which may reach a length of two and one-half inches.

FIG. 106. The chersis sphinx, *Hyloicus chersis* (*Sphingidae*).

The click beetles (*Elateridae*) are the adults of "wireworms," and nearly all are wood borers. The eyed elater (*Alaus oculatus*) is our most conspicuous form (Plate XII, Fig. 3). The click beetles are so named because of the clicking noise produced by rubbing the pronotum against the mesonotum.

The stag beetles (*Lucanidae*) are formidable-looking beetles which are sometimes called pinching bugs (Fig. 127). The jaws of the male are larger than those in the female, and frequently males engage in bitter combat over the attentions of a female, who sits nonchalantly watching the battle, ready to accept the victor.

The lady bugs or ladybird beetles (*Coccinelidae*) comprise a group known to every boy and girl who sing, "Lady bug, lady

bug, fly away home," to them. The ladybird beetles are mostly predáceous, feeding on plant lice in both the adult and larval stages; and both stages are usually found in abundance where plant lice abound (Plate XIII, Fig. 9).

The scarabs (*Scarabaeidae*) comprise a very large group of diverse beetles which exhibit a great deal of variation in form and habit. Among these are the rose chafer (*Macrodactylus subspinosus*), the tumble bug (*Canthon laevis*), the May beetle or June bug (*Lachnosterna fusca*), the grape vine beetle (*Pelidnota punctata*) (Plate XII, Fig. 2), and myriads of others.

FIG. 107. The striped sphinx, *Deilephila lineata* (*Sphingidae*).

Of these the tumble bugs are most interesting with their habits of carefully making spherical balls of dung which they roll to their burrows and reshape, finally laying their eggs in them. It will be noted that the anterior margin of the head is so shaped that it can be used as a spade in separating desirable quantities of dung from the mass. The tumble bugs show some remarkable adaptations which are worthy of discussion. The tarsi on the fore legs are usually wanting, and the distal ends of the tibiae are toothed.

The teeth serve to rake the stringy, non-nutrient particles from the dung. The inner surfaces of the tibiae are rounded to enable the shaping of the ball. When a ball as large as a walnut is formed, the beetles roll it to an excavation. In rolling the ball the tumble bug uses the sharp claws on the hind feet as pivots which hold the ball and prevent its getting away. This necessitates walking on the front legs as shown in Fig. 134.

When the ball is placed in the nest, the female reshapes it into an egg-shaped mass and then divides it, laying an egg in each part. Frequently she remains with the mass, removing molds which appear from time to time; and after the young are born, she dies, having fulfilled her mission in life. The male has probably died of senility long before. Every student should read more about these interesting insects in Henri Fabre's *The Life and Love of the Insect.*[1]

[1] Appleton Co., publishers.

The larvae of fireflies have already been referred to. The adults are inconspicuous, nocturnal, soft-bodied beetles which rest on plants during the day. The photogeny of fireflies has always been a matter of controversy, although it is recognized as being very efficient because it is a bright and cold illumination. It has been

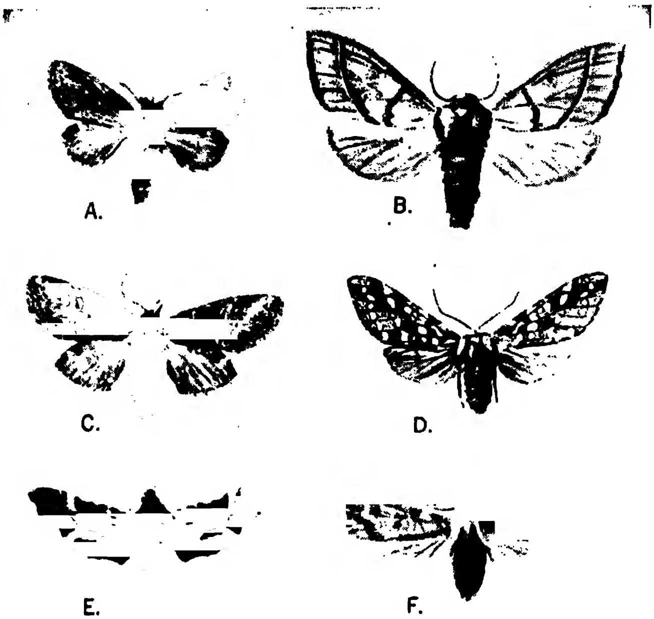


FIG. 108. Common small moths. A. *Heterocampa guttata*, male; B. *Nadata gibbosa* (*Notodontidae*); C. *Heterocampa guttata*, female (*Notodontidae*); D. The hickory borer, *Halisodota caryae* (*Arctiidae*); E. *Amphion nessus* (*Sphingidae*); F. *Halisodota sp.* (*Arctiidae*). E. original; all others from Ill. State Bull. Nat. Hist.

found, however, that the light is produced by oxidation resulting from the action of an enzyme luciferin on luciferase.

The firefly is active on dark nights in midsummer, and the light is undoubtedly of value in aiding the insect to find its way about. There is usually a difference in the flashing of the two sexes, especially during the mating season. The female rests on a plant flashing slowly, while the male flies about flashing at frequent intervals. In this way recognition is effected.

The most conspicuous photogenic beetles in the world are

elaterids or click beetles found in Central and South America. One large form (*Pyrophorus*) has two large structures resembling eyes on the thorax, from which a brilliant light is emitted.

The leaf beetles (*Chrysomelidae*) comprise a large and variable group which are found only on plants. The most conspicuous members of the family include the Colorado potato beetle or "potato bug" (*Leptinotarsa decimlineata*) (Plate XIII, Fig. 4), the asparagus beetle (Plate XIII, Fig. 8), flea beetle (Plate XIII, Fig. 10), cucumber beetle (Plate XII, Fig. 1), and tortoise beetle (Plate XIII, Fig. 7). The greenish-gold "jewel bug," found on goldenrod, euphorbia, and milkweed, is the most brilliantly colored native species.

FIG. 109. The regal moth (*Citheronia regalis*) and its larva. Larva after Packard, *Mem. Acad. Nat. Sci.*; adult after Felt, Bull. N. Y. State Mus.

The carrion beetles (*Silphidae*) may be found under excrement and the bodies of dead animals. If weather conditions are right, hundreds may be trapped in a single night by placing a mason jar containing decaying meat or a fish head and covered with cheesecloth in which a small slit has been made, in the ground with the surface of the jar almost flush with the surrounding earth. If the top of the jar is covered with dead leaves and left over night, the collector will probably find an abundance of carrion beetles the next morning.

Perhaps the most interesting of the silphids is the sexton or burying beetle (Fig. 130). This beetle is orange and black, and it is widely distributed. If you place a dead mouse or bird on the lawn at night and cover it with crossed sticks so that other animals may not carry it away, you may find that on looking for it the

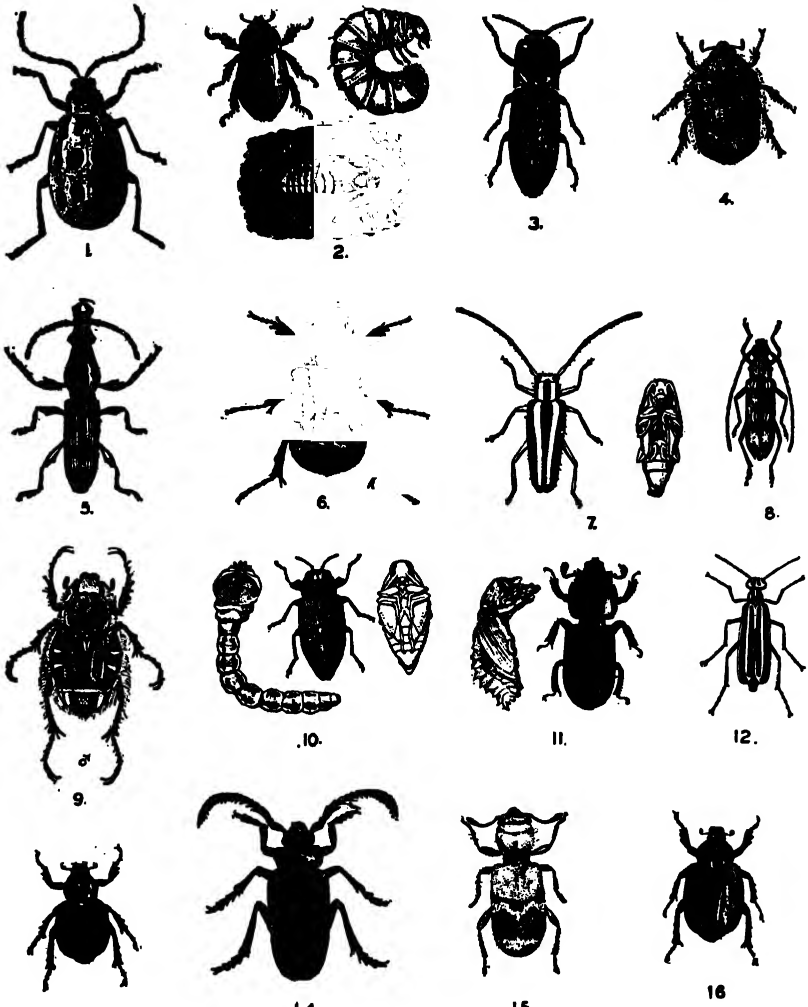


PLATE XII. Some common beetles. 1. Cucumber beetle, *Diabrotica 12-punctata* (*Chrysomelidae*); 2. Grape vine beetle, *Pelidnota punctata* (*Scarabaeidae*), after Riley; 3. Eyed elater, *Alaus oculatus* (*Elateridae*); 4. Flower beetle, *Euphoria inda*, after Chittenden; 5. Snout beetle, *Eupsalis minuta*, after Felt; 6. *Euphoria sepulchralis* (*Scarabaeidae*); 7. Round-headed apple tree borer, *Saperda candida* (*Cerambycidae*); 8. *Euboria geminata* (*Cerambycidae*); 9. *Trichius piger* (*Scarabaeidae*), after Chittenden; 10. Flat-headed apple tree borer, *Chrysobothris femorata* (*Buprestidae*); 11. *Passalus cornutus* (*Passalidae*), after Riley; 12. Blister beetle, *Eppicauta vittata* (*Meloidae*), after Chittenden; 13. Odor beetle, *Osmoderma Glabra* (*Scarabaeidae*); 14. *Prionus umbricornus* (*Cerambycidae*); 15. *Clerus quadriguttata* (*Cleridae*), after Felt; 16. *Osmoderma eremicola* (*Scarabaeidae*). Courtesy Ill. State Lab. Nat. Hist.

next morning the carcass has disappeared. By digging at the spot you will find that the body has been neatly buried. The beetles (*Necrophorus*) excavate beneath the carcass until it has sunk

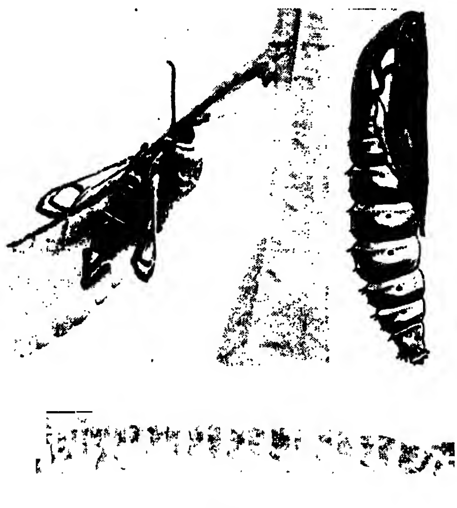


FIG. 110. The peach tree borer, *Sanninoidea exitiosa* (*Aegeriidae*). After Snodgrass, Farmer's Bulletin, Bur. Ent., U. S. Dept. Agric.

FIG. 111. Head of a butterfly. *a*. Antennae; *l*. Labial palpus; *p*. Proboscis or sucking tube. After Folsom and Wardle, *Entomology*, courtesy P. Blakiston's Son & Co.

beneath the surface of the earth. They then cover it, and the females lay their eggs on the carcass so that the newly hatched larvae will be supplied with an abundance of food. Another conspicuous carrion beetle is shown in Fig. 130.

FIG. 112. The comma butterfly, *Polygonia comma* (*Nymphalidae*). After A. H. Clark.

There are too many beetles to allow of discussion here, but the student may find them in dead logs (*Buprestidae, Cucujidae, Elateridae*); beneath the bark, where the engravers make fantastic designs on the wood (*Scolytidae*); in fungi, where very small fungous forms (*Cryptophagidae*) abound; in water (*Hydrophilidae, Haliplidae,* and *Dytiscidae*); and, in fact, almost everywhere.

Water forms are discussed in more detail under the subject of aquatic animals.

Homoptera (like wings). This order includes a large number of sucking insects which are also "bugs," but which differ from the Hemiptera in that all of the wings are of the same texture, and they are usually membranous or transparent. Many of them are also much smaller than the true bugs, although one, the cicada or seventeen-year locust, is quite large. The aphids or plant lice (*Aphididae*), jumping plant lice (*Chermidae*), froghoppers or spittle insects (*Cercopidae*), the whiteflies (*Aleyrodidae*), scale insects (*Coccidae*), leaf-hoppers (*Cicadellidae*), the cicadas (*Cicadidae*), and the wood brownies or tree-hoppers (*Membracidae*) are the principal members of the order. All of the Homoptera are destructive and difficult to control, but they are an extremely interesting group and worthy of discussion and observation. No student should overlook this group in his field studies, because some of the most spectacular insects in the world are to be found in this order.

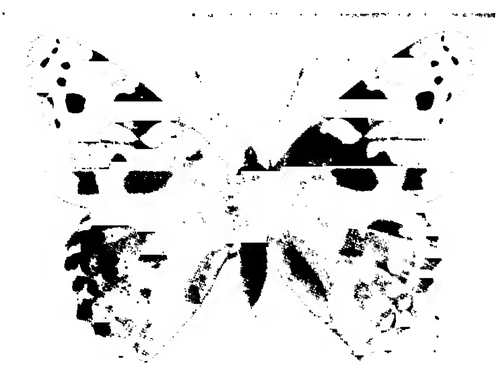


FIG. 113. The thistle butterfly, *Vanessa cardui* (*Nymphalidae*). After A. H. Clark.

FIG. 114. The papaw butterfly, *Papilio marcellus* (*Papilionidae*). After A. H. Clark.

The cicada (the seventeen-year locust is also a cicada), or harvest fly is the large, clear-winged insect that sings loudly in late summer. The music is produced by means of stridulating organs composed of membranes stretched over rounded chambers located one on each side of the abdomen. There are several species of cicadas, all of which are closely related and of somewhat similar habits.

The seventeen-year locust (*Magicicada*) or periodical cicada is the largest and most highly colored species.

Cicadas lay their eggs in the young twigs of trees by splitting the stems. The eggs hatch into white "grubs" which feed on the inner parts of the stem, thus killing the twig. When the dead twig breaks, the larva drops to the ground and 'digs in." The seventeen-year species is supposed to spend about seventeen years as a "grub" in the ground where it feeds on the roots of plants, finally emerging from the ground and crawling upon a tree where the outer skin dries. The skin then splits lengthwise on the back, and the adult slowly emerges. There are "locust years" in which there is an unusual number of cicadas. These do not apply only to the seventeen-year species but to the others as well. Every five to seven years there is a preponderance of these destructive insects, and their larval cases are found in great numbers on the trunks of trees. These periodic occurrences are usually quite localized, however. The nymph or larva is equipped with "digger feet" in front, but at the last molt these are lost, there being no further need for them since the adults are aerial. In the larval stage, the cicada is destructive to the roots of growing plants.

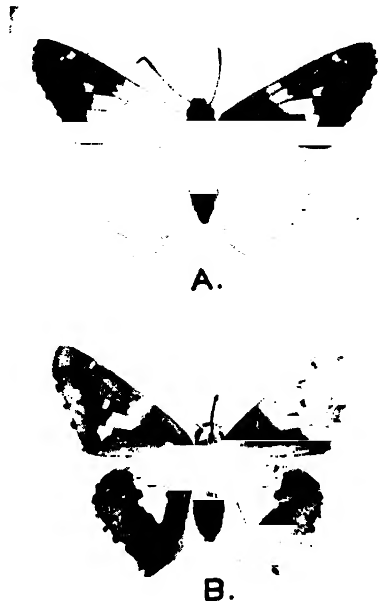


FIG. 115. The silver-spotted skipper, *Epargyreus tityrus* (*Hesperiidae*). A. Upper side; B. Under side.

While, as has been indicated, in certain groups the female is the more dangerous sex, there is a tendency in nature to eliminate the male wherever possible. Nowhere is this better demonstrated than among the aphids or plant lice. These tiny green, red, or black insects are found on stems and leaves of plants everywhere. In some cases the kind of aphid can be identified by the plant on which it is found, there being more or less of a specific selectivity;

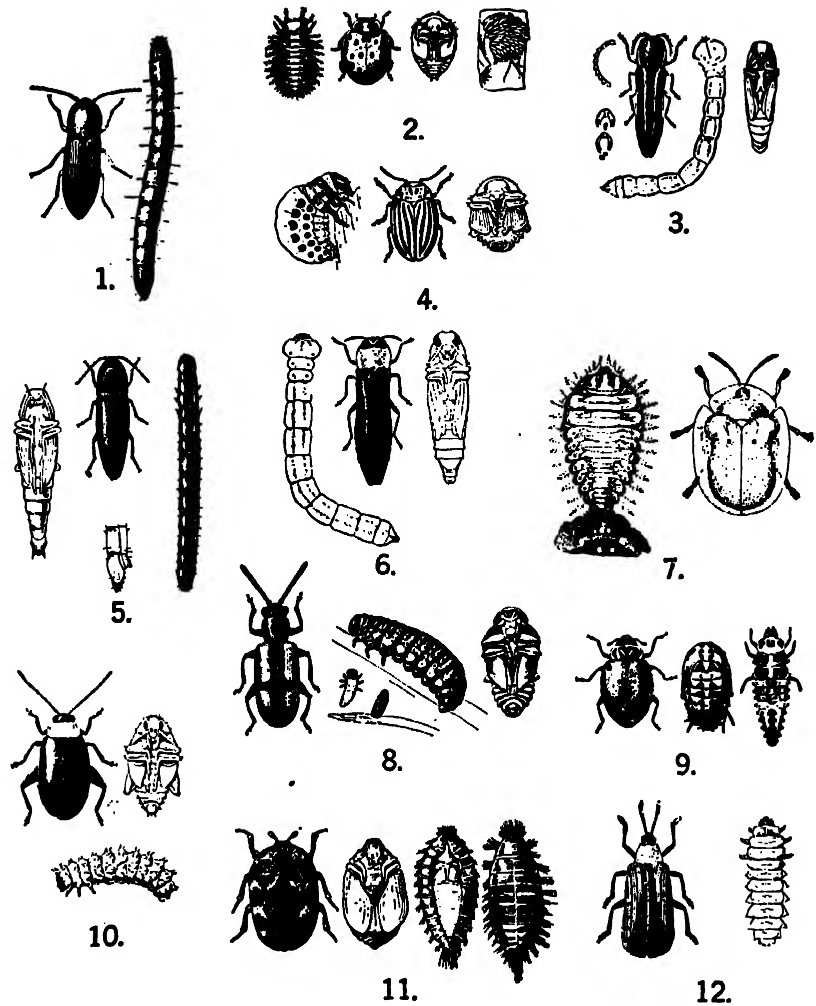


PLATE XIII. Some common field and garden beetles. 1. Wheat wireworm (*Elateridae*); 2. Mexican bean beetle (*Coccinellidae*); 3. Two-lined oak borer (*Elateridae*); 4. Potato beetle (*Chrysomelidae*); 5. Wheat wireworm (*Elateridae*); 6. Corn wireworm (*Elateridae*); 7. Golden tortoise beetle (*Chrysomelidae*); 8. Asparagus beetle (*Chrysomelidae*); 9. Lady bird beetle (*Coccinellidae*); 10. Beet leaf flea beetle (*Chrysomelidae*); 11. Carpet beetle (*Dermestidae*); 12. Locust leaf miner (*Chalepus-Chrysomelidae*). Courtesy Bur. Ent., U. S. Dept. Agric.

and some species are termed woolly aphis (Fig. 86), "cocklebur aphid," "elm leaf aphid," black peach aphis (Figs. 84, 85). Many species have dual hosts, while others are facultative, feeding upon many kinds of plants.

In most of them the fertilized eggs remain over winter; and in the spring these eggs hatch into females called "stem mothers" which reproduce parthenogenetically during the summer, producing wingless females only. These wingless or agamic[1] females produce several generations of similar wingless forms until the plant is well stocked with them. Then a generation of winged females is produced, and these migrate to the secondary host, where they again produce wingless females. Later another generation of winged females is produced, and these migrate back to the primary host on which the stem mothers were born. These give rise to both male and female forms, which mate, the females eventually laying eggs which winter over and from which new stem mothers hatch in the spring. There are variations of vivipary and ovipary and also differences in the generations among the various species of aphids; but it is remarkable that males are only produced in the final brood of the season. It seems that the male is only necessary in order to produce eggs which will withstand the rigors of winter. The common apple aphid, which ranges over a wide degree of latitude, produces no males at all in southern regions where the winters are mild.

FIG. 116. The common American swallowtail, *Papilio polyxenes* (*Papilionidae*). A. Male; B. Female.

Associated with aphids, one usually finds the adults and larvae of ladybird beetles which feed upon them, and ants which attend them, as explained elsewhere.

[1] Agamic = without marriage.

The aphids are also subject to the attacks of small parasitic Hymenoptera (*Braconidae*) which lay their eggs within their bodies and in the eggs (Fig. 9).

The "spittle insects," or froghoppers, are the creatures that construct the masses of white froth or "spittle" that are so frequently found on plants, especially Queen Anne's lace (*Daucus carota*), during the summer months. These insects are small bugs which can be identified by small teeth or spines located on the tibiae (Fig. 23).

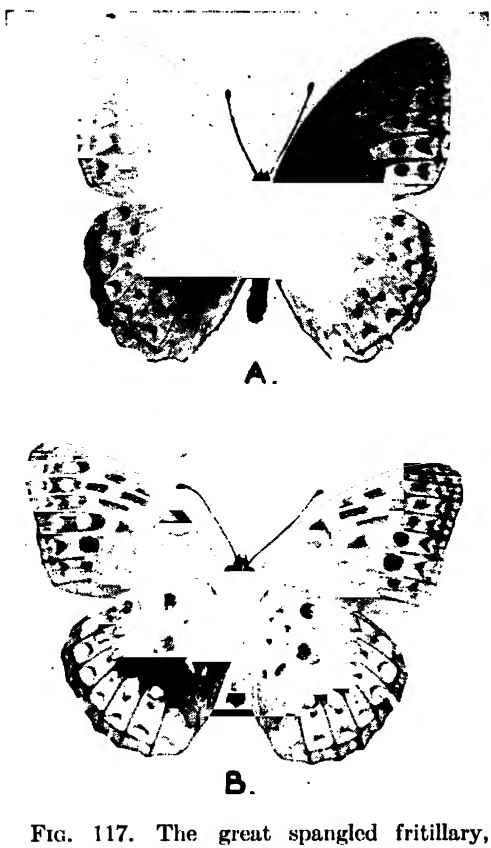


Fig. 117. The great spangled fritillary, *Argynnis cybele* (*Nymphalidae*). A. Upper side; B. Under side.

The tree-hoppers, wood brownies, or membracids are weird-looking creatures which are usually quite angular. The thorax extends considerably backward over the abdomen. They are sometimes supplied with prolongations which are extenuations of the pronotum and which sometimes make them resemble thorns or horns, although they also assume other fantastic shapes (Fig. 18). The membracids abound everywhere, and they are most easily captured by sweeping the shrubs and herbaceous plants. Many of them rest on the stems of twigs where they insert their slender, piercing, sucking mouth parts and drink the sap of the plant. Like the froghoppers, most of the membracids cover their eggs with froth.

Related to the membracids are some smaller insects with somewhat similar habits known as leaf-hoppers, jassids, or cicadellids.

The commonest species are nile green in color, although one rather common form is conspicuously colored with red, green, and yellow. The leaf-hoppers are found almost everywhere and can be taken in numbers by the sweep net. Some membracids and leaf-hoppers are shown in Fig. 88.

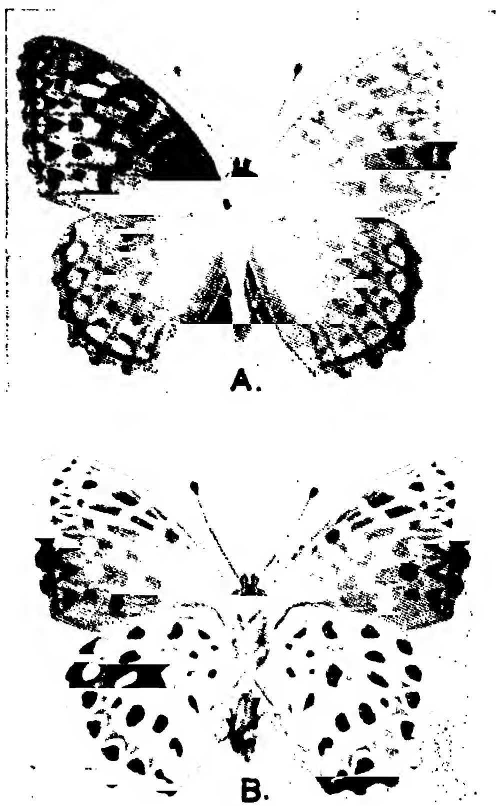


FIG. 118. The aphrodite fritillary, *Argynnis aphrodite* (*Nymphalidae*). A. Upper side; B. Under side. After A. H. Clark.

Another large group of homopterous insects includes the scale insects and the mealy bugs. To this group belongs the Mexican cochineal insect which occurs on cacti and from which dyes are made. The lac insect of the tropics from which shellac is made, the oyster shell scale, cottony cushion scale, and numerous others also belong here. They are all small, and most of them quite destructive. One of them, the San Jose scale, threatened the orange industry of California; and only the finding of a natural enemy, the Australian ladybird beetle, saved the oranges of that state. Most of the scales secrete a waxy, resinous substance which completely covers them and protects them. The adults are legless and wingless.

The whiteflies, *Aleyrodidae*, are the tiny, whitish insects usually found on house plants. In the wild they are always on the undersides of leaves. The adults of both sexes have four wings. They sometimes reproduce parthenogenetically. The eggs are placed on stalks, and the curious larvae are surrounded with a waxy

secretion. A great quantity of honey dew is secreted by the larvae, and this exudes through the anal orifice, which, strangely, is located on the back, just behind the middle of the body. The metamorphosis in this group comes near to being complete or holometabolous, the young being larvae.

Fig. 119. The meadow fritillary, *Brenthis bellona* (*Nymphalidae*).

Hemiptera (half-winged). This order includes the true bugs, and the name of the order refers to the fact that the distal portion of the wing is transparent, while the upper or proximal portion is opaque, thus giving it the appearance of being only half a wing. The wings overlap at their tips. That all bugs are insects but not all insects are bugs is a fact to remember. All of the members of this order have sucking mouth parts which in each case consist of a needle or awl-like proboscis which the insect inserts into plants or the bodies of other animals and through which the juices of the food organism are drawn. The group is frequently referred to as "the sucking order." The length and stoutness of the sucking tube vary in

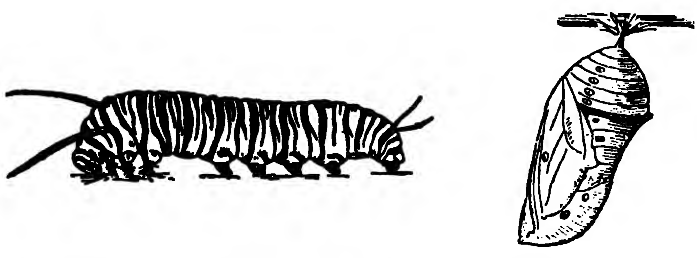


Fig. 120. Larva and chrysalis of the monarch butterfly (*Nymphalidae*). Courtesy Bur. Ent., U. S. Dept. Agric.

different bugs, being short and robust in the giant water bug and long and slender in the kissing bug. The antennae usually have less than five segments. All of the bugs undergo a gradual metamorphosis, and the young, which are called nymphs, are born without wings.

There are many kinds of bugs, most of which have unpleasant odors. They are variable in their habits and habitats. Some live

in the water where they prey on other insects and even fish, while other predatory forms fly about, seeking unwary victims. The majority of them, however, feed on plants by inserting their beaks into stems and leaves and sucking plant juices. Since they do not feed on the solid portions of the plant, their control is difficult. Among the more important economic bugs are the chinch

Fig. 121. The red admiral, *Vanessa atalanta* (*Nymphalidae*). A. Upper side; B. Under side.

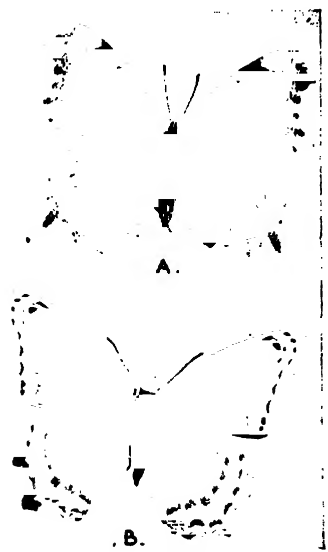


Fig. 122. A. The mourning cloak, *Aglais antiopa* (*Nymphalidae*); B. The red-spotted purple, *Basilarchia astyanax* (*Nymphalidae*).

bug (*Lygaeidae*) which is destructive to timothy, corn, and cereals, and which is a black and white bug with the legs and bases of the antennae red; the squash bug (*Coreidae*); the stink bugs (*Pentatomidae*) which give berries a bad taste; red bugs (*Pyrrhocoridae*), some of which feed on scale insects; and the assassin bugs (*Reduviidae*) which feed on other insects. Some of the other more common members of this order are the water striders (*Gerridae* and *Veliidae*) (Fig. 27), ambush bugs (*Phymatidae*) (Plate X, Fig. 4), stilt bugs (*Neididae*) (Plate X, Fig. 5), water scorpion (*Nepidae*) (Fig. 34), water boatmen (*Corixidae*) (Fig. 33), backswimmers (*Notonectidae*) (Fig. 33), and lace bugs (*Tingidae*) (Fig. 89).

In all of these families there are numerous species, but the family habits are usually common to all members.

The more interesting water bugs are discussed under Water Animals, while some of the more common terrestrial forms are shown in Plate X.

Diptera (two wings). The flies, mosquitoes, craneflies, midge flies, robber flies, moth flies, fruit flies, flesh flies, fungus gnats, houseflies, gall gnats, and horseflies belong to this order.

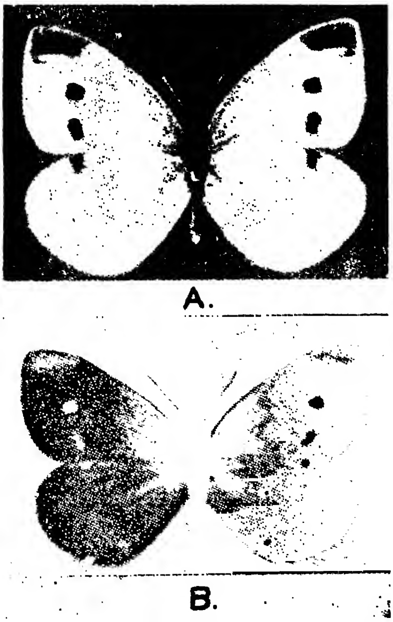


FIG. 123. The cabbage butterfly, *Pieris rapae* (*Pieridae*). A. Summer form; B. Spring form. After A. H. Clark.

Many insects which are commonly called flies, such as firefly, scorpion fly, dragon fly, ichneumon fly, and lantern fly, are not flies at all. All of the true dipterous insects have only one pair of wings which are attached to the mesothorax. In place of the second pair of wings, they have a pair of knobbed, thread-like balancers or halteres which are attached to the metathorax. There are some true flies, however, which are wingless. These include the louse flies, bat ticks, bee lice, and sheep ticks. The economic importance of this order is too well known for general discussion here. Some of them are bloodsuckers (horse flies—*Tabanidae*, Fig. 36; black flies—*Simuliidae*, Fig. 41; mosquitoes—*Culicidae*, Fig. 35; and some members of other families); others destroy crops (the maggots in beets, turnips, radishes, apples, and a host of other destructive larvae; and the gall gnats—*Cecidomyiidae*); and quite a number are parasitic on and in domestic animals, resulting in serious losses at times. Among the latter are the botflies or warble flies (*Oestridae*) which lay their eggs in the bodies or on the hair of horses, sheep, and cattle; the blow flies (*Calliphoridae*, Fig. 138); and the flesh flies (*Sarcophagidae*) which breed in carcasses or sores. The housefly (*Muscidae*) lays its

eggs in manure or decaying organic matter. One member of this family, *Stomyxys calcitrans* (Fig. 136), is a blood-sucker. It is called the stable fly, and it is often pestiferous to humans. The housefly is a factor in the spread of typhoid and other diseases. The function of the mosquito as a carrier of yellow fever, malaria, and the dreaded elephantiasis or filariasis hardly needs to be men-

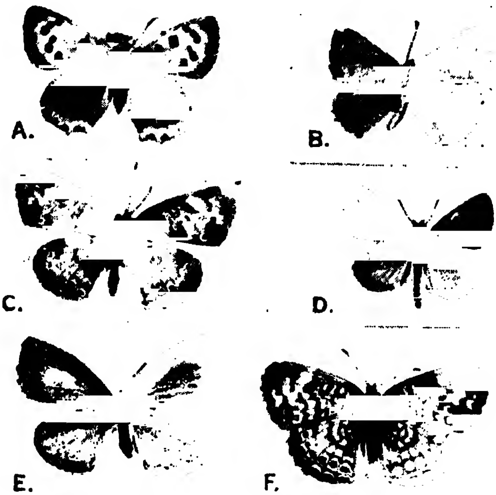


FIG. 124. Common small butterflies. A. American copper, *Chrysophanus hypophlaeus* (*Lycaenidae*), upper side; B. Same, under side; C. Pearl crescent, *Phyciodes tharos* (*Nymphalidae*); D. Numitor skipperling, *Ancyloxypha numitor* (*Hesperiidae*); E. Common blue, *Lycaena pseudargiolus* (*Lycaenidae*); F. Silver crescent, *Phyciodes nycteis* (*Nymphalidae*).

tioned. The malaria-carrying mosquito, Anopheles, is widely distributed, the writer having found it frequently in Pittsburgh.

There are about 50,000 known species of flies. About 10,000 of these are found in North America. While most of our native flies are terrestrial, a number of them breed in water. These include the large, mosquito-like craneflies (*Tipulidae*); the soldier flies, *Stratiomyiidae*, which develop from the familiar rat-tailed maggot found in ponds and streams; the horseflies (*Tabanidae*); the black flies (*Simuliidae*); the midge flies, *Chironomidae* and *Dixidae;* and the mosquitoes (*Culicidae*). The *Anisopidae* or *Rhyphidae* greatly resemble craneflies and might easily be mis-

taken for them. There are small flies found on foliage or seen on windows which greatly resemble tiny moths. These belong to the family *Psychodidae.*

The long-legged metallic blue or green medium-sized flies found in damp places and often seen in gardens belong to the family *Dolichopodidae.* The males of certain species have elongated front tarsi which are ornamented with brilliant hair tufts. During the breeding seasons, the male promenades back and forth on the surface of an exposed leaf, strutting as though he were walking on his toes. He is watching for a female; and when the female passes by, the male immediately lifts his front foot as though beckoning to her to "come over." The hair tuft or "flag" is used to attract her attention.

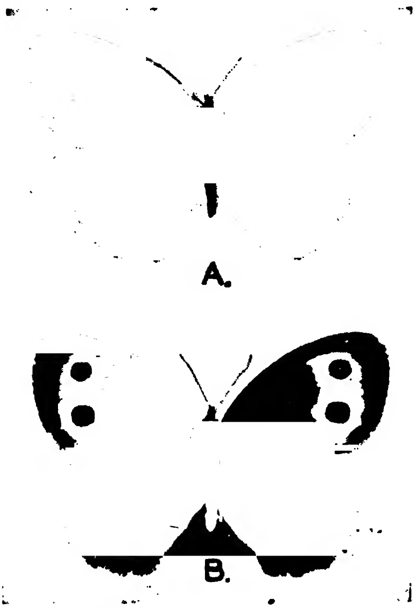


FIG. 125. A. The clouded wood nymph, *Cercyonis alope*, variety *nephele;* B. The common wood nymph, *Cercyonis alope* (*Nymphalidae*).

The dance flies (*Empididae*) are those dark-colored flies that hover in swarms over water or in the region of shrubs, about dusk. They are frequently seen above a path through the woods. The swarm of flies moves up and down continuously. The male dance fly carefully prepares an ornate capsule, composed mainly of his own saliva, which he presents to the female in courtship with the same gusto that a young swain presents a box of chocolates to his lady love. While positive proof is lacking, the evidence indicates that the capsule, which the female eats, acts as a love philter and stimulates sexual desires.

The robber flies (*Asilidae,* Fig. 139 I, J, K) and the tachinid flies (*Tachinidae*) are predatory and feed upon other insects which they capture in flight. The vinegar gnats or fruit flies (*Drosophilidae*) are the small flies that hover about fruit. They breed in bananas and in bruised portions of apples and other fruits.

FIG. 126. Upper left, the little wood satyr, *Neonympha eurytus* (*Nymphalidae*); Upper right, the common wood nymph, *Cercyonis alope* (*Nymphalidae*); Lower left, the Baltimore, *Melitaea phaetona* (*Nymphalidae*); Lower right, the American Copper, *Chrysophanus hypophlaeus* (*Lycaenidae*). A. Upper side; B. Under side. After A. H. Clark.

Many of them lay their eggs on the skins of melons and other fruits. The tiny gnats found hovering about bracket fungi or in damp woodlands are fungus gnats—*Mycetophilidae.* They are the adults of the tiny maggots found when many types of fungus plants are broken apart. The midge flies, *Chironomidae,* are mosquito-like flies with plumose antennae. They are adults of the bloodworms found in ponds and streams.

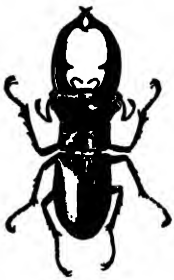


Fig. 127. A stag beetle (*Lucanus elaphus*). After Kellogg, *American Insects,* courtesy Henry Holt and Co.

All of the flies undergo a complete metamorphosis with egg, larva, pupa, and adult stages, although a few species are viviparous and therefore bring forth living young. The maggot or larva is short, legless, thick-bodied, and worm-like. It lacks a well-defined head, and the mouth parts are poorly developed as a rule. The coarctate pupae are oval or cylindrical with rounded ends. They are enclosed within the hardened, larval skin; and no parts of the contained insect are visible. The statement that "little flies grow up to be big flies" is erroneous. Every winged fly is mature, no matter how small it is. There are a great many more families of flies than are mentioned here. Some flies are shown in Fig. 139.

Hymenoptera (membranous wings). The bees, ants, wasps, gall flies, ichneumon flies, and sawflies belong to this order, which is

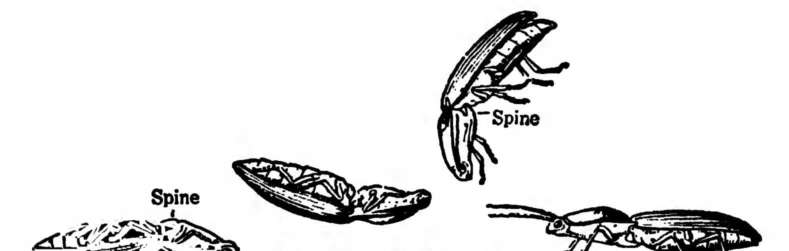


Fig. 128. A click beetle (*Elateridae*) turning over. After Schmiel from Hegner, *Invertebrate Zoology.*

perhaps, as a whole, the most highly specialized of all insects. This order includes many diverse individuals. A complete summation of the numerous families is included in the chapter on Classification.

The hymenopterous insects have two pairs of membranous

wings which are transparent or translucent, and they have comparatively few veins (see Wings of insects). The hind wings are usually much smaller than the front ones and the wings are held together by rows of small hooks or hamuli located on the anterior margin of the hind wings. The mouth parts are quite variable within the group, some members having suctorial and others mandibulate types. The abdomen is composed of six or seven visible segments. The ovipositor of the females is modified for stinging (bees and wasps), sawing (sawflies), or boring (ichneumon flies and horntails) (Figs. 142–143). The larvae of the hymenoptera are also diverse, some being maggot-like and legless (bees, flies, ants); others are cater-

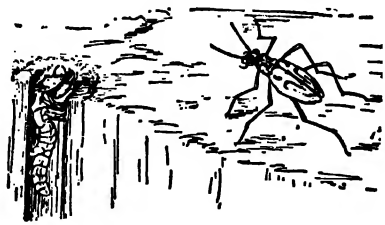


FIG. 129. Adult tiger beetle (*Cicindelidae*) and a larva in its burrow. After Lutz, *Fieldbook of Insects*, courtesy G. P. Putnam's Sons.

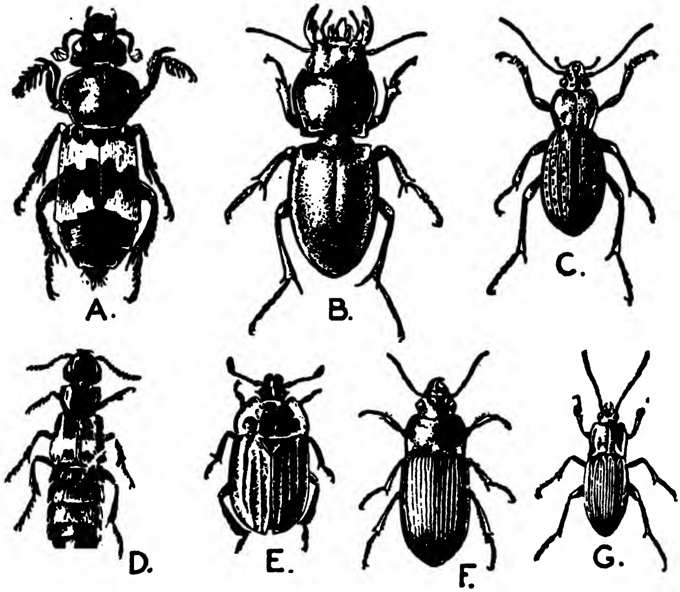
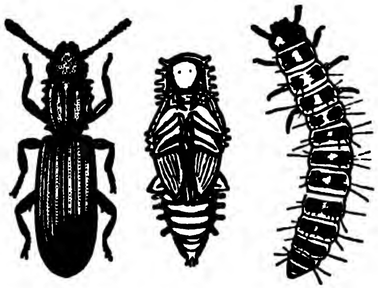


FIG. 130. Some common beetles. A. Burying or sexton beetle (*Silphidae*); B. Stag beetle (*Lucanidae*); C. Fiery hunter (*Carabidae*); D. Rove beetle (*Staphylinidae*); E. Carrion beetle (*Silphidae*); F. and G. Common ground beetles (*Carabidae*). After Lutz, *Fieldbook of Insects*, courtesy G. P. Putnam's Sons.

pillar-like (sawfly) (Fig. 141); while still others may have thoracic legs (larvae of gall flies). The metamorphosis includes the egg, larva, pupa, and adult stages; and it is therefore complete or indirect (holometabolous).



A. B. C.

FIG. 131. Saw-toothed grain beetle, *Oryzaephilus surinamensis* (*Cucujidae*). A. Adult; B. Pupa; C. Larva. Courtesy Bur. Ent., U. S. Dept. Agric.

From man's point of view this order of insects is both good and bad. In it are those insects which supply honey and beeswax. Others, such as the ichneumons and braconids parasitize destructive caterpillars, plant lice, and the larvae of wood-boring beetles (Figs. 143, 145). The digger wasps, mud wasps, and hornets devour numerous harmful insects including mosquitoes, grasshoppers, cicadas, and caterpillars (Fig. 149). Some of the ants are excellent scavengers and quickly remove putrefying matter. In the tropics we always allowed the ants to clean the skeletons of our animal specimens. But there are also pestiferous household species and the wood-destroying carpenter ants which do considerable damage. The bees carry pollen from one flower to another and thus make possible the development of numerous fruits. The bumble bee is of inestimable value in pollinating the flowers of clover.

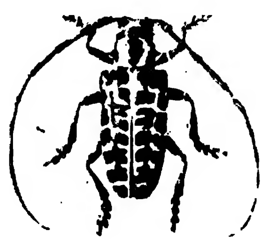


FIG. 132. The cottonwood borer (*Plectrodera scalator*). Courtesy Bur. Ent., U. S. Dept. Agric.

On the other hand, the sawflies are very destructive to growing crops by cutting into the stems of plants with their saw-toothed ovipositors in order to deposit their eggs; and the leaf-cutter bees almost completely ruin many plants including roses. The leaf-cutters cut circular sections of leaves and petals of flowers and use them to line the interiors of their nests which are placed in the ground. The mining bee is sometimes harmful to timber. The stem flies (*Cephidae*) and the gall flies (*Cynipidae*) also do considerable damage by laying their eggs in the stems of wheat and other herbaceous plants. Many more

could be added to both the beneficial and harmful lists if space would permit. One of the striking features of the Hymenoptera is the widespread and often solicitous care of the young.

The order includes a vast number of families and species which exhibit such a diversity of structures and habits as to preclude their complete discussion here; and the student is referred to specialized works for further information.

A general and abbreviated summary of the hymenopterous insects will help the student to appreciate the numerous kinds that are included in the group. There are many groups of bees, wasps, and ants which are frequently encountered everywhere; and all of them are included in ten superfamilies, some of which contain quite a number of individual families.

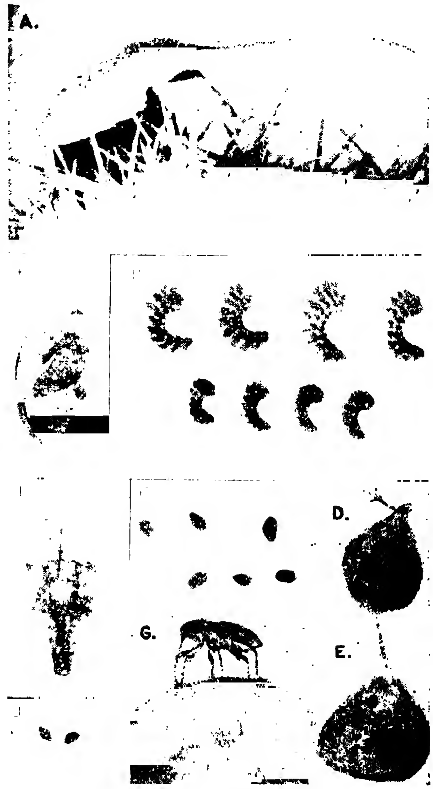


FIG. 133. The chestnut curculios. A. Large chestnut weevil (*Curculio proboscideus*); B. Larvae of the large weevil; C. Larvae of the lesser weevil; D. Hole of emergence of the large weevil; E. Hole of emergence of the lesser weevil; F. Eggs of the large weevil; G. Adult of the lesser weevil (*Curculio auriger*); H. Pupa of the lesser weevil; I. Pupa of the large weevil; J. Eggs of the lesser weevil. From Tech. Bull. 130, courtesy U. S. Dept. Agric.

(1) *Tenthredinoidea.* These are the sawflies, of which there are several kinds with diverse habits. Most of them have caterpillar-like larvae which feed upon leaves or tunnel in the pith of twigs. *Cimbex americana* (family *Tenthredinidae*) and its larva are shown in Fig. 141. The adult of this species has a wing spread of almost two inches. *Tremex columba*, the horntail or pigeon tremex (*Siricidae*), is shown in Fig. 142. The latter is a wood-boring species. The female inserts the ovipositor into trees; and when

the eggs have been deposited, she cannot withdraw it again. The dead bodies of this wasp are often found projecting from the trunks of trees.

(2) *Ichneumonoidea.* These are the parasitic wasps which lay their eggs in caterpillars, aphids, eggs of insects, and in the oötheca of roaches. There are three principal families, all of which are beneficial since they destroy many harmful insects. The *Ichneumonidae* are the largest of this group. *Megarhyssa* (*Thalessa*) is shown in Fig. 143. It drills through the wood of trees with its long, thread-like ovipositor, which is composed of three very long parts, into the burrows of horntails where its larvae kill the horntail larvae. The males lack the abdominal appendages. The *Braconidae* are much smaller than most ichneumon flies; and they usually lay their eggs in the backs of caterpillars, although some of them are so small that they parasitize aphids or their eggs. Figure 7 shows a parasitized caterpillar. The eggs are laid by the female within the body of the caterpillar; and the young are nourished by feeding upon the body substance of their host. Just before the host dies, the larvae pupate; and the picture shows the pupae protruding from the moth larva. The *Evaniidae* or ensign wasps have short, blunt, laterally-compressed abdomens which are held aloft and seem to be attached to the top of the thorax. The ensign wasps seek the egg cases of cockroaches in which to deposit their own eggs.

FIG. 134. The tumble bug or dung beetle. After Fabre.

(3) *Cynipoidea.* This group includes the gall wasps of the family *Cynipidae*, all of which are small. These tiny wasps sting the stems, leaves, and other parts of plants, and deposit their eggs in the plants. The injury caused by puncturing the stem causes the unusual swellings or galls that are seen on a great number of plants.

(4) *Chalcidoidea.* The chalcid flies are also parasitic upon other insects as a rule, although a few of them are plant-eaters, one species being destructive to the seeds of clover. A cocoon of the

Cecropia or Emperor moth (or numerous other cocoons and butterfly pupae, for that matter) may not produce a moth or butterfly at all; but instead, many of these parasitic chalcids may emerge. They belong to the family *Chalcididae.* As a whole the group is beneficial; and some of them are being raised artificially and then released so that they will parasitize destructive, uncontrollable insects such as the European corn borer.

(5) *Serphoidea.* This group includes two principal families. The *Pelecinidae* includes the black, shining pelecinid wasp, the

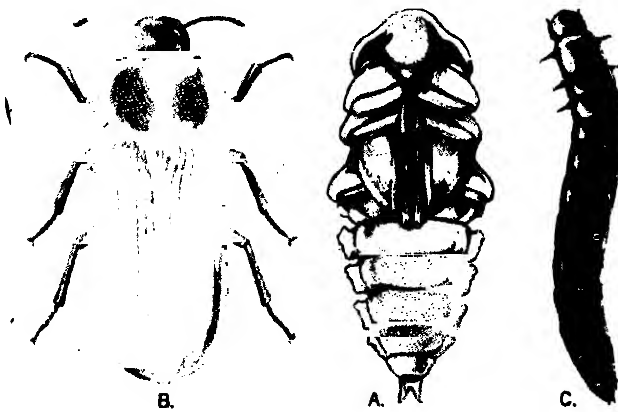


Fig. 135. Life history of the meal worm (*Tenebrio obscurus*). B. Adult; A. Pupa; C. Larva. After Cotton, Tech. Bull. 95, courtesy U. S. Dept. Agric.

female of which has a very much elongated abdomen (Fig. 144). On the male, the abdomen is rather short. Males of the pelecinid wasp are extremely rare. It is a valuable insect inasmuch as it parasitizes the larvae of June beetles by inserting the long abdomen into the ground to reach the beetle larvae. The *Proctotrupidae* are among the smallest insects, and they breed in the eggs of other insects. Some species even go into the water, using the wings in swimming, in order to parasitize the eggs of water insects. These tiny wasps render a very valuable service to man by greatly reducing the numbers of insects which affect food plants.

(6) *Formicoidea.* These are the ants, all of which belong to a single family *Formicidae.* There are many kinds of ants; and while there is considerable variation in size, color, and habits

among the numerous species, all of them are readily identifiable by their general, familiar form. In ants the three body regions—head, thorax, and abdomen—are distinct, with the thorax usually narrower than the head and abdomen. The abdomen is attached to the thorax by a slender petiole which always bears one or two swellings or tubercles (Fig. 158). The swellings in the petiole are a sure mark of identification. The mouth parts are adapted to chewing, and the antennae are of moderate length. The legs are long, slender, and adapted to running. None of our native ants possess stings, although a number of species can inflict irritating wounds with their jaws.

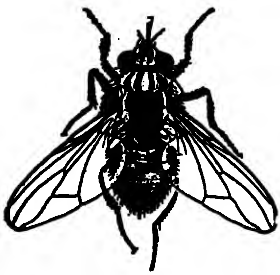


FIG. 136. The biting stable fly, *Stomyxys calcitrans* (*Muscidae*). After Kellogg, *American Insects*, courtesy Henry Holt and Co.

The largest native species is the black carpenter ant (*Camponotus*) which is nearly three-quarters of an inch long (Fig. 156). This species excavates the dead heart wood of trees, but it also proves troublesome at times by injuring timber and composition wall boards in buildings.

The little yellow ant or little red ant, *Monomorium pharaonis* (Fig. 158), and the little black ant, *Monomorium minimum* (Fig. 153), are often troublesome household pests. They are the extremely small ants that find their way into pantries, iceboxes, and kitchens.

The thief ant, *Solenopsis molestus*, has minute yellow workers which burrow into the nests of other ants and prey upon the larvae and pupae of the larger species. They seize their victims and scamper into their own burrows which are too small for the adults of their victims to enter in pursuit.

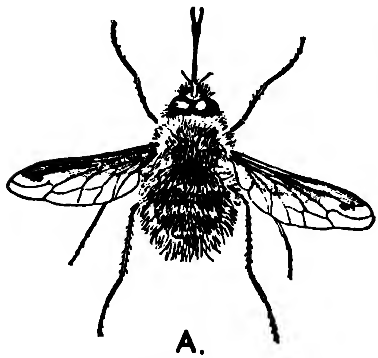
One species of shed-builder ants is native to eastern United States. It sometimes builds a nest in which it keeps aphids. The nest is made of powdered dead wood glued in masses on the branches of plants or on tree stumps.

The Argentine ant, *Iridomyrmex humilis*, is an introduced species which has become a serious pest in orchards because it protects and nurtures destructive aphids; and also a household pest, especially in the South. It is an omnivorous, colonial species which nests under pavements, about houses, stone piles, or most anywhere. In the household it eats almost everything, and it

spreads all over the house. It has even been known to attack babies with serious results. The mound-building ants (*Formica exsectoides*) are those which construct the large ant hills. The head and thorax are reddish, and the legs and abdomen are much darker.

The red slave-maker, *Formica sanguinea,* constructs low, obscure mounds of earth under stones or logs and around dead tree stumps. It enslaves the small, blackish ant, *Formica fusca.*

The shining Amazon, *Polyergus lucidus,* is a widely-distributed, reddish, slave-making species which is virtually helpless without its slaves. Their mouth parts are sickle-shaped jaws adapted only to fighting. The forays conducted by the slave-making ants are worth seeing. They simply overwhelm their victims, killing all adults encountered and carrying off the young.



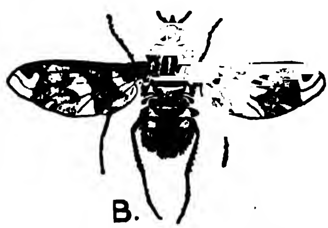


FIG. 137. Bee flies. A. *Bombylius;* B. *Ectoprata.* After Kellogg, *American Insects,* courtesy Henry Holt and Co.

The corn-field ant, *Lasius niger,* and several other species in the same genus are small, brown ants that make small mounds. These ants collect and nurture plant lice and coccids; and for this reason they are objectionable. One species which nurtures coccids in the roots of corn is considered a serious pest.

Dr. Wheeler reports an inquiline or guest ant, *Leptothorax emersoni,* which lives only with another species that builds its nest in swamps or bogs, usually in moss. This species, with the harvesters, fungus-growers, and others is discussed in the general discussion of ants which follows.

(7) *Chrysidoidea.* These are the cuckoo wasps which lay their eggs in the nests of other wasps which provide food for their young. Many nest-building wasps place paralyzed caterpillars in the nest with their eggs so that the young will have food available. The

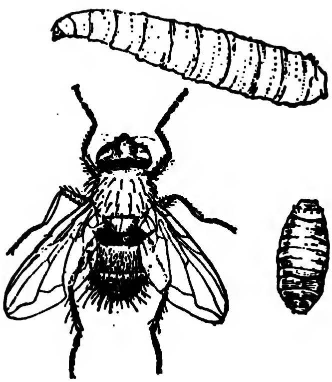


FIG. 138. The flesh fly or blowfly (*Calliphora*). After Kellogg, *American Insects*, courtesy Henry Holt and Co.

larvae of the cuckoo wasp then devours the provender provided for the young of the host species, and sometimes it even eats the young of the host species. However, the invader sometimes meets with resistance from the host wasp; and occasionally it is killed. But the cuckoo wasp is covered with a hard coat; and when attacked, it rolls its body into a ball. The hardened body covering protects the vulnerable parts of the body against the sting of its adversary, as a rule. There is but one family, *Chrysididae*, including mostly metallic green or blue species.

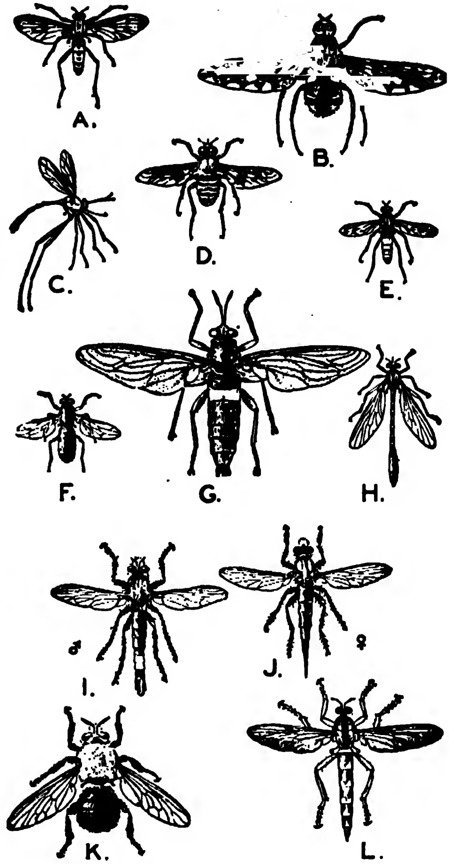


FIG. 139. Some common flies. A. *Leptis mystacea* (*Leptidae*); B. *Spogostylum simson* (*Bombyliidae*); C. *Systropus macer* (*Bombyliidae*); D. *Exoprosopa fascipennis* (*Bombyliidae*); E. *Psilocephala haemorrhoidalis* (*Therevidae*); F. *Scenopinus fenestralis* (*Scenopinidae*); G. *Mydas clavatus* (*Mydaidae*); H. *Leptogaster flavipes* (*Asilidae*); I. and J. *Erax rufibarbus*, male and female (*Asilidae*); K. *Dasyllis thoracica* (*Asilidae*); L. *Asilus sericeus* (*Asilidae*). After Lutz, *Fieldbook of Insects*, courtesy G. P. Putnam's Sons.

(8) *Vespoidea*. These are the typical wasps; and the group includes the yellow jacket, hornet, and the other social wasps, as

well as velvet ants. The velvet ants are usually brightly colored wasps, and their bodies are quite hairy. The females are wingless, and they can sting. The eggs are probably laid in the nests of other wasps, and the young are parasitic on the young of the host species. The winged males are harmless. The velvet ants are typically southern, ground-inhabiting wasps. They are ant-like in appearance, and belong to the family *Mutilidae.*

The *Psammocharidae* are the slender, blue or black, solitary wasps, frequently with orange bands. They prey chiefly upon spiders; and their nests are usually in the ground. These are the smoky-winged wasps which run about over the sand with their wings continually jerking. The family was formerly called *Pompilidae*. A few of them make mud nests under stones.

The *Eumenidae* include the potter wasps which make jug-like nests of mud on plants. They prey upon caterpillars and beetle larvae which they paralyze by stinging. These larvae are placed in the nests with the eggs so that when the young are born, they will have food available. All of the wasps that sting spiders, insects, and insect larvae always sting through the ventral surface of the bodies of their victims because the nerve cord is ventrally located. The victims are only paralyzed and do not die. This is a remarkable behaviorism, for if they killed their victims, they would putrefy before their own young are born.

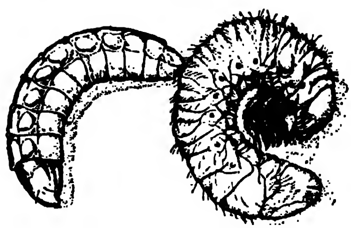


FIG. 140. Larva of a robber fly (*Asilidae*) killing a grubworm. Courtesy U. S. Dept. Agric.

The social wasps belong to the family *Vespidae* which includes yellow jackets, hornets, mud daubers, and other wasps. The large, rounded, or elliptical papier maché nests on the branches of trees are the nests of yellow jackets. Within the nests are stories or platforms, each of which is composed of numerous cells.

Another wasp, *Polistes*, makes a similar nest except that it has only one platform of cells, and it lacks the papier maché covering. All of the social wasps are beneficial and all of then can sting.

(9) *Sphecoidea.* These include diverse kinds of wasps, some of which are mud daubers, while others are diggers. The group includes eight families as follows:

The *Psenidae* are obscure forms which probably nest in rotten wood.

The *Oxybelidae* are inconspicuous wasps which nest in sand and which prey upon small flies.

The *Crabronidae* are small, elongated, black wasps, often with yellow markings. They nest in sand banks and prey upon bugs.

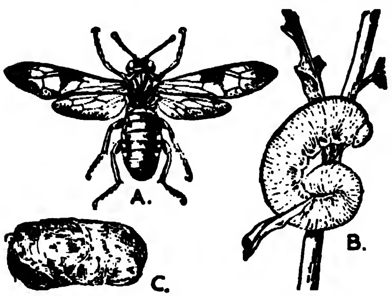


FIG. 141. A sawfly. A. Adult; B. Larva; C. Cocoon. After Lutz, *Fieldbook of Insects*, courtesy G. P. Putnam's Sons.

The *Philanthidae* are very small digger wasps with occasional cross markings.

The *Trypoxylonidae* are usually minute wasps in which the abdomen is long and narrow. They are usually all black, although a few of them are marked with red. They make their nests in minute holes and in chinks in stones. A British Guiana species is discussed elsewhere.

The *Larridae* are also inconspicuous, ground-nesting wasps which prey upon aphids and upon orthopterous insects. Some of them have red abdomens.

The *Bembecidae* are ground-nesting wasps that are usually seen flying close to the ground over dry sand. Their abdomens are usually marked with cross bands of greenish yellow and black. They stock their nests with bugs as a rule.

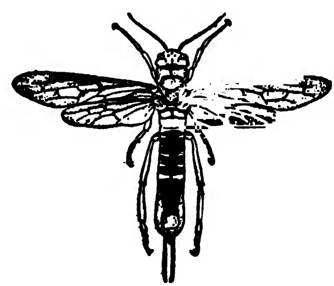


FIG. 142. A horntail, the pigeon tremex. After Lutz, *Fieldbook of Insects*, courtesy G. P. Putnam's Sons.

The *Sphecidae* are the thread-waisted wasps, some of which nest in the ground while others make nests of mud. The latter are called mud daubers. They gather mud in pellets which they carry in their jaws, and the pellets are used to make vertical tiers in which the cells are made. The cells are separated by thin partitions of mud. In each cell an egg is placed; and food, consisting of paralyzed spiders and caterpillars, according to the species, is provided for the young.

In this group are to be seen some interesting behaviorisms. Figure 149 shows *Sphex* (*Amnophila*) placing caterpillars in its underground nest.

(10) *Apoidea.* This group is a large one including the honey bees, bumble bees, mason bees, leaf-cutter bees, and numerous others.

The *Apidae* includes the honey bees which are discussed in the text.

The *Halictidae* are the sweat bees which make burrows in the ground. Each burrow consists of a single opening, but under-

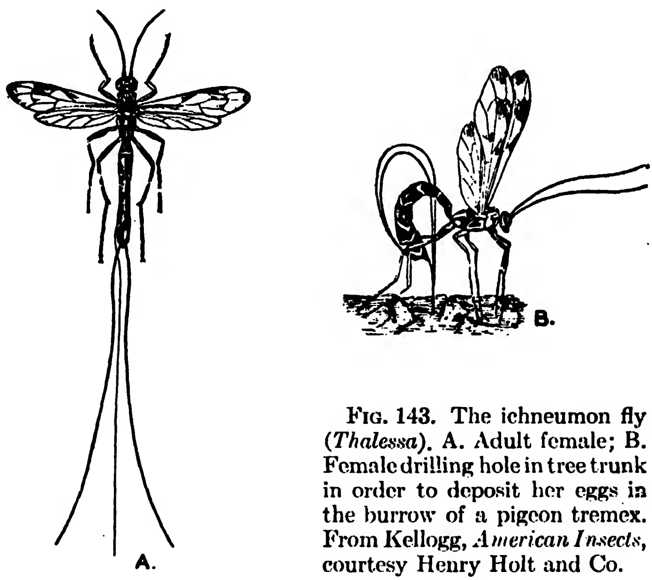


Fig. 143. The ichneumon fly (*Thalessa*). A. Adult female; B. Female drilling hole in tree trunk in order to deposit her eggs in the burrow of a pigeon tremex. From Kellogg, *American Insects*, courtesy Henry Holt and Co.

ground there are many branches to the nest. This family also includes the *Andrenidae* which are often placed in a separate family.

The *Anthophoridae* are large, pollen-collecting bees which are more bee-like in appearance than the preceding groups. They nest in clay banks; and like the preceding families many nests may be constructed close together in a colony. Some of them are nocturnal.

The *Bombidae* include the familiar bumble bees or "humble bees" which also nest in the ground. They are pollen-gatherers, and they have pollen baskets on their hind legs which the wasps do not have. These are discussed a little more in detail, later on.

The bees are often broken up into numerous families by some authors; and there is still some uncertainty as to the details of classification in the order Hymenoptera, as a whole. At the present time wing venation is the fundamental basis for determining groups and individuals; and only technically trained specialists are qualified to authentically differentiate among species. For that reason, the student should be content to learn as many families and individuals as possible by field studies and from illustrations. More detailed information about the families, is included in the classification of animals, Chap. I.

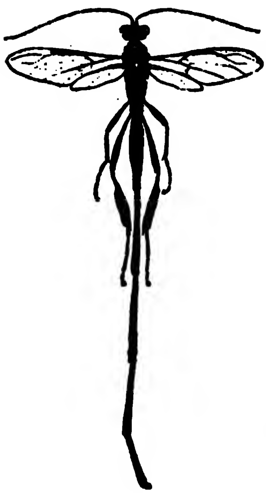


FIG. 144. The pelecinid fly (Hymenoptera). After Kellogg, *American Insects*, courtesy Henry Holt and Co.

The Hymenoptera is distinct in having highly organized societies in several groups. The honey bee (*Apidae*) is a well-known social member of the order. In the hive there may live upwards of 30,000 individuals representing three distinct castes—queen, worker, and drone. The queen is the regal individual, ruling alone. The workers are unfertilized females, and these far outnumber the other castes. They are usually the only kind seen outdoors. The drones are males whose sole function is to fertilize new queens. The drones are much larger than the workers, and they are reared in larger cells. The worker bee can sting viciously, but she can sting only once because she loses the stinging organ.

The hive of the bee is constructed by the workers from waxen exudates from their own bodies. On the abdomen are tubercular plates or wax scales on which the wax accumulates by sweating. This is transferred to the mouth where it is mixed with a fluid which makes it plastic. The comb is constructed of hexagonal cells, some of which are larger than the others. The crevices are sometimes filled with propolis, the sticky exudation from the buds or leaf axils of various plants. In the larger cells the queens and drones are to be reared. The queen, attended by workers, lays her eggs in the cells; and the eggs hatch into whitish, legless, maggot-like grubs, which are carefully attended by workers which bathe them and feed them with regurgitated material. Later

the larva spins a cocoon about itself and pupates, eventually emerging as a winged adult. The developmental period is about 29 days. The newly emerged workers act as nurses for a time, or until the cephalic glands are exhausted. Then they assume the duties of foragers. The larvae that are destined to become queens are fed a special mixture of pollen and nectar; and this royal food seems to have an effect upon the fertility of the emerging queen. The workers perform all of the household tasks such as gathering pollen and nectar, taking care of the young, constructing the hive, and so forth.

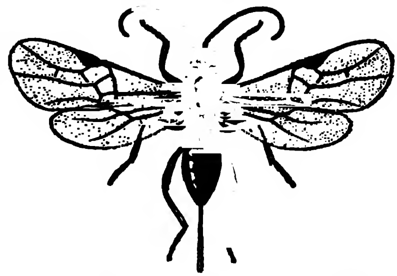


Fig. 145. A parasitic wasp (*Microbracon*). Courtesy Bur. Ent., U. S. Dept. Agric.

When the nectar is taken from the flower by the worker bee, it is stored in honey sacs located in the abdomen for transportation to the hive, where it is placed in the cells. The thin, watery fluid is evaporated to reduce the water content. This is effected by the vibrations of the wings. During the season for gathering nectar, the workers may be observed standing at the entrance of the hive, vibrating their wings and causing a current of air to flow through it. After a while, the ripened honey is transferred to other cells where the worker injects a preserving fluid (formic acid) with her sting. When the honey is reduced to the proper constituency, the cell is sealed.

Fig. 146. A black digger wasp (*Chlorion ichneumoneum*). Courtesy Ill. State Lab. Nat. Hist.

In the brood chamber where the young are reared, the new queens emerge; and immediately there is a "battle royal" which is a fight for supremacy among the newly emerged queens and between them and the old queen. As a rule the queen bee can be safely handled and does not sting because she usually reserves her sting for a rival female. Eventually the defeated queens leave the hive, followed by a number of workers; and new colonies are

established by these departing groups. These emigrations are called swarms, although sometimes outside disturbances also cause swarming. In rural districts, when the bees swarm, the people beat tin pans, sing, yell, and play musical instruments to settle the swarm. Most wild bees are ones that have escaped during the swarming period. In apiaries, where honey is produced for commercial purposes, artificial combs are made; and numerous queen cells are made so as to increase the number of queens. The queens are removed and used to establish new colonies. Sometimes the workers lay unfertilized eggs.

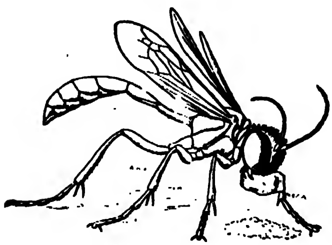


Fig. 147. A digger wasp (*Sphex*) using a pebble to tamp the dirt over its nest. After Peckham from Folsom and Wardle, *Entomology*, courtesy P. Blakiston's Son & Co.

The queen mates only once, after which she seems to exercise control over the eggs she lays; and the unfertilized eggs always produce drones while the fertilized eggs produce females, although the manner of control is not completely understood. The queen may live for four or five years, retaining the seminal fluid received from the drone, in the spermatheca, which opens into the egg passage. It has already been suggested that the food is a determining factor in the production of queens. In times of distress the drones are driven from the hive by the workers.

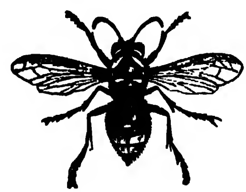


Fig. 148. The white-faced hornet. Courtesy Ill. State Lab. Nat. Hist.

Bumble bees (family *Bombidae*). The organization of a bumble bee colony is not so highly specialized as that of the honey bee. The hibernating female starts a colony in the spring, utilizing frequently the deserted nest of a field mouse or the burrow of a mole. The eggs are laid in a mass of pollen and nectar. The larvae which hatch from the eggs devour the surrounding mixture; and when mature, they spin cocoons about themselves. When the imago or adult emerges, the empty cocoon is sometimes used for storing honey. At first only workers are produced; and these relieve the queen of all of her duties of gathering nectar and caring for the young. The workers are of different sizes, the smaller ones acting as nursemaids

and builders of the nest while the larger ones immediately engage in gathering nectar. Unlike the honey bee, the males of the bumble bees work. These are the ones usually seen outdoors. In the latter part of the summer, both males and females are produced; but when winter arrives, the older queens, the males, and the workers die, leaving only the newer queens to survive. These establish the colonies in the next season. The bumble bee can sting as often as it desires without losing its sting.

Social wasps (*Vespidae*). There are three kinds of social wasps belonging to the family *Vespidae.* The papier maché nests which are frequently seen attached to trees are the homes of rather formidable wasps known as *Vespa maculata* (Fig. 148). The nest is made from the shreds of weather-torn wood. The shreds are pulled off with the jaws and masticated with a salivary fluid which waterproofs the material. Within the nest are numerous cells or combs in which food is stored. The colony is started by a solitary queen which produces a generation of workers. These immediately assume the duties of completing the nest and caring for the young. The young are fed at first upon material regurgitated by the workers; and later they are given a diet of caterpillars, flies, and other insects. The workers are modified females, as in other Hymenoptera. The workers also lay eggs, but these produce only males. Unlike the honey bee, the male is a laborer. These wasps sometimes survive the milder winters of temperate zones; and in the tropics some of them maintain the colonies for several years. Other social forms make their nests in the ground (*Vespa vulgaris* and *V. germanica*). These carry paralyzed spiders and caterpillars into their nests for the young to feed upon when they are hatched.

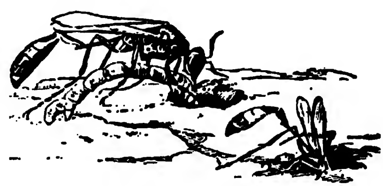


FIG. 149. A sphecid wasp. (*Sphex*) placing a measuring worm in its nest. After Kellogg, *American Insects*, courtesy Henry Holt and Co.

Digger wasps are solitary species which make burrows in the ground. When the eggs are laid, the female stings other insects or spiders, paralyzing them but not killing them. These helpless victims are stored with the eggs so that the young will have a supply of food to nourish them sufficiently for completing their development. The life history is completed within the nest made

by the mother. It is remarkable that the female apparently knows that the nerve cords are ventrally located and therefore stings her victims from beneath. Most of the diggers belong to the superfamily Sphecoidea which are slender-waisted, medium-sized wasps; and their victims include grasshoppers, spiders, measuring worms, and even cicadas. Other diggers include the family *Pompilidae,* which are long-legged, solitary wasps which are usually blue or black, some of them having orange bands. They prey upon spiders, chiefly. The *Bembecidae* are medium-sized diggers marked with cross bands usually of black and greenish yellow. They are commonly found in sandy regions where they fly close to the ground. In most cases the diggers, when their nests are constructed and when the eggs have been laid, will pick up a pebble with the jaws and then tamp the earth in the opening of the burrow so as to conceal it (Fig. 147).

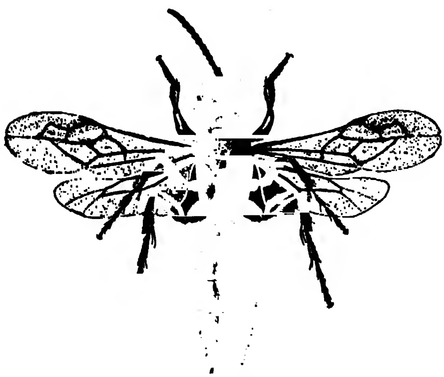


Fig. 150. A black digger wasp (*Tiphia popillavora*). From Circ. 346, courtesy U. S. Dept. Agric.

Mud daubers. Many wasps construct their nests of mud. The mud is shaped into pellets which are carried in the jaw. The type of nest is dependent upon the species. Some of the *Sphecidae* construct a single tier of mud cells on the rafters in barns. The *Eumenidae* includes the mud wasps that construct several tiers of cells side by side in an effect somewhat like a pipe-organ. The potter wasps (Fig. 23) are those which make a single, jug-like nest suspended from a twig or leaf.

The small *Trypoxylonidae* construct their nests in the stems of plants or other hollow places. Keyholes, glass tubes, and even keys themselves have been utilized for nesting places. The Trypoxylonids separate the cells with mud partitions. Before the cell is sealed, the egg is deposited in it; and several paralyzed spiders are placed with the egg. The thin-walled partition of mud protects these from intruders. When the young hatch, they devour the spiders and then pupate. The adult, upon emerging, eats a hole in the mud wall and escapes.

The writer had a most interesting experience with these wasps in British Guiana. They were really pestiferous creatures because they placed mud in hollow keys and especially in the keyholes of microscope cases, making it necessary to put a gummed label over the keyhole when the case was not in use. To secure the

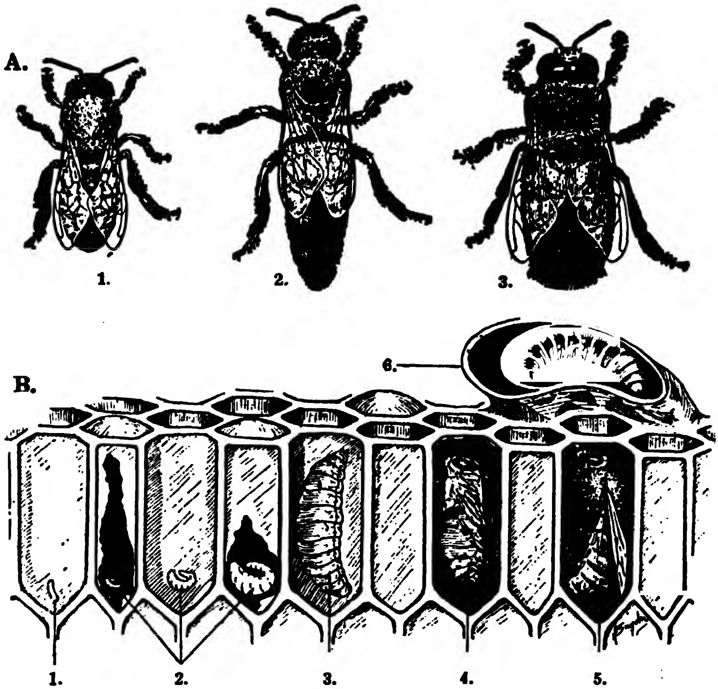


FIG. 151. The honey bee. A. Castes: 1. Worker; 2. Queen; 3. Drone; B. Section of comb showing the honey bee in various stages of development: 1. Egg; 2. Three stages of larvae; 3. Fully developed larva; 4. Pupa; 5. Adult queen ready to emerge; 6. Queen larva in queen cell. A. courtesy U. S. Dept. Agric.; B. courtesy Gen. Biol. Supply Co.

nests of these wasps for the collection, glass tubes, sealed at one end, were inserted through holes punched in the sides of a cardboard box just below the lid, with the open ends of the tubes exposed. In a day or two the wasps had utilized all of the tubes for making their egg cells. A tube eight inches long has ten mud partitions separating cells, in each of which an egg has been deposited and provender consisting of paralyzed small spiders has been included in each cell for the expected young.

The first egg laid was next to the closed end of the tube, with

six mud partitions between it and the open end of the tube. The last egg laid was in a cell next to the open end of the tube with only one thin, mud partition between it and the outside. The remarkable feature of this was that the last egg laid was the first to hatch. When the young wasp completed its metamorphosis, it chewed a hole in the partition and emerged. Each succeeding egg developed in turn until finally the first egg developed last;

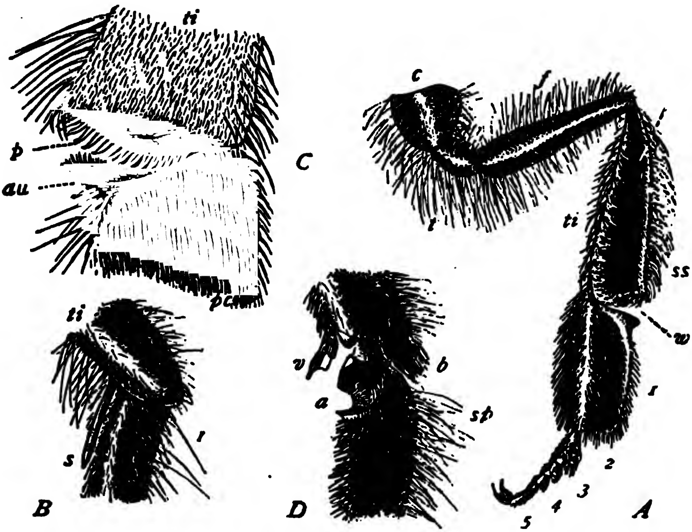


FIG. 152. Adaptive modifications of the legs of the worker honey bee. *A*. Outer aspect of left hind leg; *B*. Portion of left middle leg; *C*. Inner aspect of tibio-tarsal region of left hind leg; *D*. Tibio-tarsal region of left fore leg; *a*. Antenna comb; *au*. Auricle; *b*. Brush; *c*. Coxa; *co*. Corbiculum; *f*. Femur; *p*. Pecten; *pc*. Pollen combs; *s*. Spur; *sp*. Spines; *t*. Trochanter; *ti*. Tibia; *v*. Velum; *w*. So-called wax pincers; *1.–5.* Tarsal segments; *1*. Metatarsus or planta. From Folsom and Wardle, *Entomology*, courtesy P. Blakiston's Son & Co.

and it, too, had only one partition to break through. After making a hole in the mud, it passed through the holes made by its predecessors in the other partitions. In all of the species of mud wasps, the metamorphic cycle is completed within the cell and the adults escape by making holes in the partitions of mud.

Gall-makers. Most of the hymenopterous gall-makers belong to the family *Cynipidae*, although some sawflies also produce galls. These are discussed under Galls.

Ants. With the termites, the ants exhibit the highest social attainments of the insect world. There are many kinds of ants,

and they are the most abundant of all living things. Their numbers indicate success, and this success may be attributed to a highly efficient social organization. From the standpoint of mechanical efficiency the ants have the most nearly perfect society on earth. Furthermore, their society is the most ancient. From a biological point of view social organization is the safeguard of a race. Long before the rise of the Dinosaurs and other animals

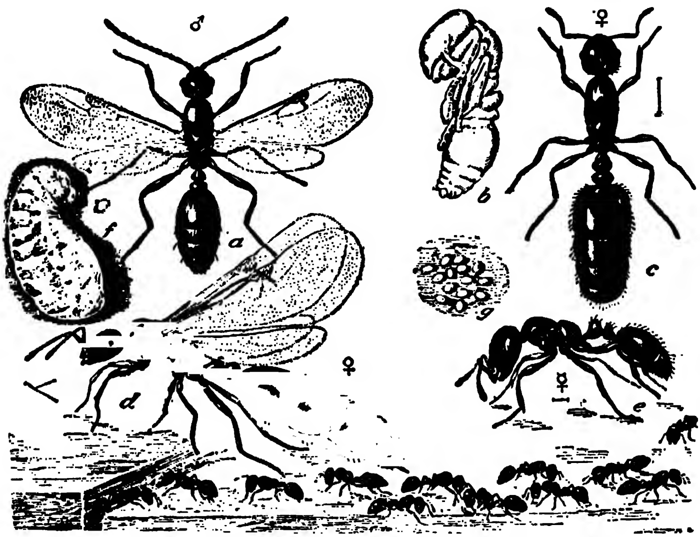


FIG. 153. The little black ant (*Monomorium minimum*). *a*. Male; *b*. Pupa; *c*. Female; *d*. Winged female; *e*. Worker; *f*. Larva; *g*. Eggs. After Marlatt, courtesy Bur. Ent., U. S. Dept. Agric.

which have long since passed into extinction, the ants had a well-organized society. These lowly creatures saw the rise and fall of human civilizations as well as diverse animal groups. The success of the ants, after careful analysis, can be attributed to the fact that each member of the society is a contributing member; and humans can well learn many lessons of importance from the study of ant societies.

In the ant colony, as in the bee hive, the queen is the regal mother although she does not rule. In fact the queen exercises no authority whatever. There are, as a rule, three castes: viz., the queen, males, and female workers. The latter are sexually imperfect females. The males and fertile females are the only ones which develop wings and they swarm into the air for the nuptial flight. Mating

takes place in midair. After the wedding journey, the males die, and the females shed their wings and begin a new colony. The females may live for years, laying eggs continuously. The workers live from one to seven years. The workers are by far the most numerous, and it is these we see industriously engaged in their various pursuits. While there are three main types of individuals in the ant colony, there is considerable variation of some of these types which show structural peculiarities by which specialized individuals may be distinguished. For instance, some of the workers have greatly enlarged heads and jaws which admirably equip them for protecting the colony against invaders. These are the soldiers. Other workers which perform special tasks also bear structural characters which differentiate them from their sister workers.

It is this assignment to the performance of special duties which makes up the society, and with each individual performing its task there is coöperation and harmony within the group. Only the strict attention to the responsibilities assigned to them makes it possible for many thousands of individuals to occupy the same nest.

As in the case of bees, the young ants are hatched from eggs which are in charge of workers. The young is a helpless, legless grub which the workers feed from their own mouths. The nurses also clean the young and transport them from one place to another where the best conditions obtain. There is an interesting interchange of food material between the nursemaid workers and the larval ants which they care for. While the nurses feed the larva, sometimes from their own mouths, they clean the larva because there are exudations from the body pores of the larva which the nursemaids seem to relish. When a nest is disturbed, the workers carry the eggs, larvae, and pupae to places of safety. This is an activity which may be seen any time during the summer by turning over stones and logs.

Anyone can observe some of the things ants do, although their actions are sometimes difficult to interpret. They may be seen to bring grains of sand from their burrows and drop them on the pile of excavated material around the entrances. In this way they construct their burrows, but sometimes an ant may be seen to drop the grain it has carried from the nest and pick up another one and take it into the burrow. This is not an aimless procedure,

for the ant carries into the nest the grains of sand which have become warm on exposure to the rays of the sun. These warm grains are carefully tucked around the eggs to incubate them; and when they cool, they are replaced with warm ones.

The members of a colony are usually hostile toward members of other colonies, and they attack intruders. When one of their own is deodorized and placed in the nest, it is usually killed at

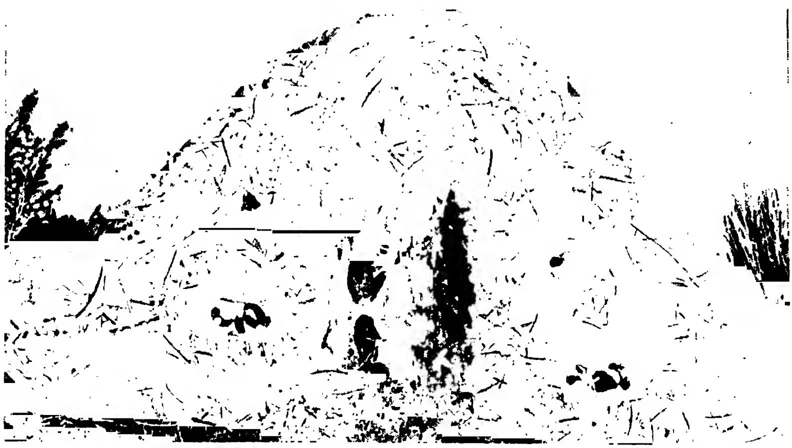


FIG. 154. A cross section of an ant nest. Photograph of a Clay-Adams preparation.

once. This is especially true if the ant is smeared with the juices of another species. If some members of a colony are removed and kept apart from the others for months, they are recognized by their fellows when they are again placed in the nest.

There is considerable evidence to show that ants are capable of communicating with one another. When a worker finds a morsel of food which it cannot carry itself, it may hurry away and later return with helpers. Communications of this sort are usually effected by stroking antennae. One of the baffling experiences of the author with the Guiana leaf-cutter ant was the fact that at the slightest disturbance along the trail, there would be a sudden appearance of myriads of huge-jawed soldiers which attacked even a gun barrel held in their path. The activities of these ants were carried on at night, and it was not possible to ascertain just how

these soldiers were notified to appear. Along the wide, beaten trails of the leaf-cutters and moving with the processions of bearers and empty-handed workers returning for another load were evil-smelling bugs which resembled the ants in form and color. Sometimes as a worker came along with its leaf section held high we noticed that there were as many as thirteen smaller ants although usually less, on the section carried. These smaller forms seemed to be castes of the same species and may have acted in a useful capacity—perhaps as a reconnaisance outfit to keep on the lookout for enemies. The amazing strength of the worker which carried not only the leaf but the host of other ants suggests an unequalled power.

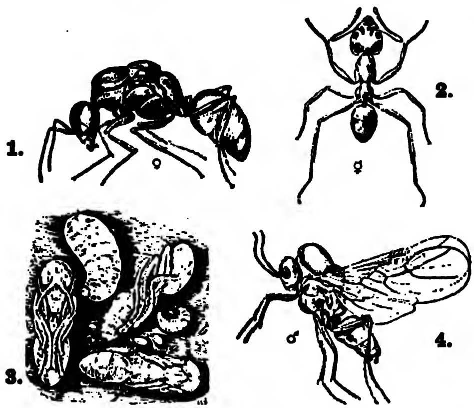


Fig. 155. The Argentine ant (*Iridomyrex humilis*). 1. Female; 2. Worker; 3. Eggs, larva, and pupae; 4. Male. After Marlatt, courtesy Bur. Ent., U. S. Dept. Agric.

The strength of ants is evidenced by their ability to carry or drag objects many times their own weight. You have often seen a tiny ant dragging a large fly. If an ant is held in a pair of forceps at the middle, it will cling to and manipulate a match stem that weighs many times more than the ant itself. Someone has said that if a human were as strong in proportion as the ant, he could hold a huge auto truck in each hand.

Another astounding habit is told of one species that uses its young as shuttles. The legless larvae are capable of emitting a hair-like thread, and the adult workers hold these larvae between their jaws and stimulate the flow of the liquid which becomes the thread. The larvae are then moved back and forth, their threads being used to line the nest.

Some ants hunt their victims in much the same manner as predatory mammals search for food. The driver ants, visiting ants, or legionary ants of tropical countries travel in immense droves, devouring everything in sight. The author has observed the Brazilian species in a column several inches wide and in a steady, unbroken stream which moved for many hours. Every-

thing in the jungles runs before the advance of these voracious creatures which do not hesitate to attack huge snakes, jaguars, and even human beings.

Most of the driver ants are blind. They have no permanent place of abode but adopt hollow logs or other places as temporary domiciles in which the new brood is reared.

Some ants enslave those of a different species. They raid the burrows of their victims and carry the eggs and young to their own homes where the captured species perform the tasks of the colony. Here is a good lesson in sociology, and it emphasizes the need for all members of a society to perform some useful task. Some of these slave-making ants have had slaves for so long that during the generations more and more responsibilities were placed on the slaves until finally the master species not only have the slaves gather the food; but they chew it, swallow it, and partly digest it. They then regurgitate this partly digested food and feed their masters mouth to mouth. When the master ants are placed in an artificial nest with an abundance of food, they starve unless their slaves are supplied to feed them. Incidentally there are myrmecophilous, or ant-loving, insects which live in ants' nests. Some of these are symbionts while others are commensal. However, Janet (Fig. 20) reported a primitive Thysanuran, *Atelura formicaria*, which would sneak up while one ant was feeding another and steal the food as the one regurgitated it into the mouth of the other.

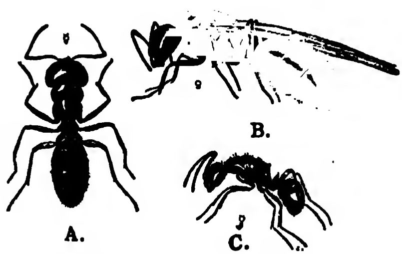


Fig. 156. The carpenter ant (*Camponotus*). A. Female; B. Major worker; C. Minor worker. After Marlatt, courtesy Bur. Ent., U. S. Dept. Agric.

The inquiline or guest ant which lives with *Myrmica brevinodis* remains in the nest, usually in burrows of its own construction, enters the burrows of the host, and climbs upon its back. It then seems to lick the body of the host ant, probably for the oily salivary secretions with which the Myrmicas cover themselves when they clean one another. The process also seems to induce the host species to regurgitate some of its food which is greedily devoured by the parasitic house guest.

In the southern part of the Middle West there are ants which

are known as honey ants (Fig. 157). In these, certain workers assume the rôle of storehouses, and the food gathered by the other workers is given to them by mouth-to-mouth contact. The receiving ants swallow this material, which consists of exudations from plants, until their abdomens become greatly distended and they look like blisters. These distended workers are attached to the upper surface of underground rooms, and their swollen bodies preclude mobility. They therefore remain together with the food

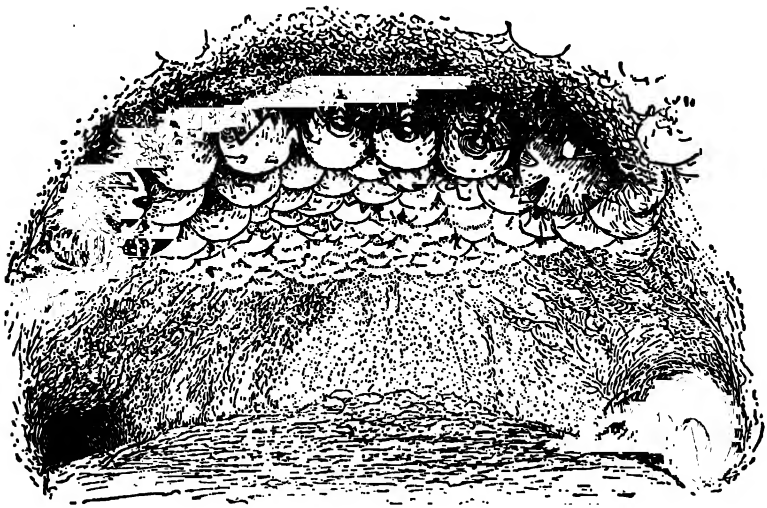


Fig. 157. Honey ants. After McCook.

safely tucked away in their bodies, free from robbing marauders. When the workers get hungry, they line up before these storage workers and are fed by regurgitation, mouth to mouth in true cafeteria style.

Harvester ants are those which gather seeds of weeds and other plants and store them in underground granaries. If the granaries become flooded, there is danger of the seeds all germinating and the provender for the winter months would be lost. In such cases these ants are said to bring the seeds to the surface where exposure to the sun dries them off and thus prevents germination. These ants usually construct runways by removing all of the débris around the opening of the nest.

Ants were among the first warriors, and sometimes war-like species advance in armies on the colonies of other ants. They

engage in bitter combat with their foes, and the manner of marching and attack would indicate a well-developed military discipline.

In Texas and tropical countries, and in a few places in eastern United States, there are ants which cut circular sections of leaves which they carry over their heads. This habit has caused them to be known as leaf-cutters or parasol ants. The leaf sections are carried to the nest and chewed into a spongy mass. The spores of fungi are placed on the pulp, and the clubbed threads of the growing fungus (mold) are used as food. Sometimes these ants will travel for great distances and completely defoliate trees in order to get material. The Texas ant cuts the sections and drops them to the ground where other workers pick them up and carry them to the nest. The writer, in the Amazon jungles, has had these ants cut sections from his shirts which had been hung up to dry, and carry them away. They also stole cigarettes and rice from the food tent. The cigarettes were cut in three sections, and each worker carried away a section in its jaws.

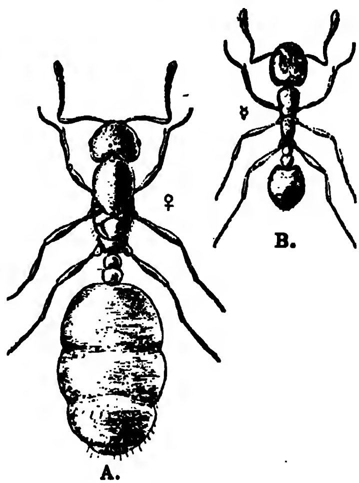


Fig. 158. Little red ant (*Monomorium pharaonis*). A. Queen; B. Worker. After Marlatt, courtesy U. S. Dept. Agric.

The nurturing of aphids by ants has been discussed under symbioses, but there are other myrmecophilus insects to be found in the nests of ants. In some tropical and native species, small beetles are kept for useful purposes. On the abdomens of these beetles are hair tufts which conceal glands from which there exudes a liquid which the ants seem to enjoy. These beetles are carefully protected and fed by their masters, the feeding usually being done from the mouths of their hosts. Sometimes the ants capture small rove beetles (*Staphylinidae*) which they keep in their nests as scavengers. These beetles keep the nests clean.

However, not all guests in the ant colony are beneficial to their hosts. Some intruders kill and devour the eggs, larvae, and pupae of the ants. Then too, internal and external parasites exact a tremendous toll. Mites are common external parasites of ants.

The student is urged to study carefully any ant colonies in the neighborhood and to observe their activities. A large magnifying glass is useful in these studies. Original observations and discoveries are much more interesting than bookish accounts. A thorough knowledge of ant societies is of great sociological value, and the student may comprehend significance in the biblical saying, "Go to the ant, thou sluggard." Many activities of ants can be observed in artificially constructed nests such as those shown in Fig. 233.

The works of Wheeler, Forel, Reamur, and others should by all means be read.

BIBLIOGRAPHY

Insects

Alexander, C. P., *The Crane-Flies of New York*, 3 parts. Cornell Univ. Exp. Sta. Mem. 38, 1920.

Andrews, E. A., "Population of Ant Mounds," *Quart. Rev. Biol.*, Vol. IV, No. 2, 1929.

Back, E. A., *Weevils in Beans and Peas.* U. S. Dept. Agric., Farmer's Bull. 1275, 1922.

Becquaert, J., *Insects as Food.* Nat. Hist. 21, 1921.

Betten, Cornelius, *The Caddis-Flies of New York State.* N. Y. State Mus. Bull. 292, 1934.

Blatchley, W. S., *Coleoptera of Indiana.* Nat. Pub. Co., Indianapolis, 1910.

——, *Orthoptera of Northeastern America.* Nat. Pub. Co., 1920.

——, *The Heteroptera or True Bugs of Eastern North America.* Nat. Pub. Co., 1926.

Blatchley, W. S., and Leng, C. W., *The Rhyncophora or Weevils of North America.* Nat. Pub. Co., 1916.

Borradaille, L. A., and Potts, F. A., *The Invertebrata.* Macmillan, 1932.

Boving, A., and Craighead, F. C., *An Illustrated Synopsis of the Principal Larval Forms of the Order Coleoptera.* Reprint Entomologica Americana, 1931.

Bouvier, E. L., *The Psychic Life of Insects.* Century, 1922.

Britton, W. E., et al., *The Hemiptera or Sucking Insects of Connecticut.* Conn. Geol. and Nat. Hist. Surv. Bull. 34, 1923.

Brues, C. T., and Melander, A. L., *Keys to the Families of North American Insects.* Published by the authors, Cambridge, Mass., 1915.

Burr, Malcolm, *Dermaptera.* Genera Insectorum Fasc. 122, 1911.

Carpenter, G. H., *Insects, Their Structure and Life.* Dent, 1928.

——, *The Biology of Insects.* Macmillan, 1928.

Caudell, A. N., *The Phasmidae or Walking-sticks of the United States.* Proc. U. S. Nat. Mus., Vol. 26, 1903.

Chapman, R. N., *Animal Ecology with Especial Reference to Insects.* McGraw-Hill, 1931.

Clark, A. H., *Animals of Land and Sea.* Van Nostrand, 1927.

——, *The Butterflies of the District of Columbia and Vicinity.* U. S. Nat. Mus. Bull. 157, 1932.

Comstock, J. H., *The Wings of Insects.* Comstock Pub. Co., 1918.

——, *An Introduction to Entomology.* Comstock Pub. Co., 1933.

Comstock, J. H., and Comstock, A. B., *Insect Life.* Appleton, 1901.

——, *How to Know Butterflies.* Comstock Pub. Co., 1920.

——, *A Manual for the Study of Insects.* Comstock Pub. Co., 1930.

Crosby, C. R., *Manual of Vegetable Garden Insects.* Macmillan, 1918.

Curran, C. H., *Families and Genera of North American Diptera.* John D. Sherman, 1934.

Dalle Torre, K. von, *Anoplura.* Genera Insectorum Fasc. 81, 1908.

Dixon, R., and Eddy, B., *Personality of Insects.* Charles W. Clark, 1924.

Dyar, H. G., *The Mosquitoes of the United States.* Proc. U. S. Nat. Mus., Vol. 62, 1922.

Eliot, I. M., and Soule, C. G., *Caterpillars and Their Moths.* Century, 1902.

Essig, E. O., *The Insects of Western North America.* Macmillan, 1926.

——, *A History of Entomology.* Macmillan, 1931.

Eyer, J. R., *A Laboratory and Field Manual of Economic Entomology.* Mimeographed edition. U. of Mich., 1931.

Fabre, Henri, *The Life and Love of the Insect.* A. and C. Black, 1914.

Felt, E. P., *Injurious and Beneficial Insects of New York State.* Bull. N. Y. State Mus., Vol. VIII, No. 37, 1900.

——, *Key to North American Insect Galls.* N. Y. State Mus. Bull. 200, 1918.

——, *A Manual of Tree and Shrub Insects.* Macmillan, 1924.

——, *A Popular Guide to the Study of Insects.* N. Y. State Mus. Handbook No. 6, 1929.

Fernald, H. G., *Applied Entomology.* McGraw-Hill, 1926.

Ferris, G. F., *The Principles of Systematic Entomology.* Stanford Univ. Press, 1928.

Folsom, J. W., and Wardle, R. A., *Entomology with Reference to Its Ecological Aspects.* Blakiston, 1934.

Forbes, W. T. M., *The Lepidoptera of New York and Neighboring States.* Cornell Univ. Memoir 68, 1923.

Forel, Auguste, *The Social World of the Ants*, 2 vols. A. and C. Boni, 1929.

Fracker, S. B., *The Classification of Lepidopterous Larvae.* Ill. Biol. Mon., Vol. II, No. 1, 1915.

French, G. H., *Butterflies of Eastern North America.* Lippincott, 1886.

Frost, S. W., *A Study of the Leaf-mining Diptera of North America.* Cornell Univ. Agr. Exp. Sta. Memoir 78, August, 1924.
Gage, J. H., *The Larvae of the Coccinellidae.* Ill. Biol. Mon., Vol. VI, No. 4, 1920.
Garman, Philip, *The Odonata or Dragonflies of Connecticut.* Conn. Geol. and Nat. Hist. Surv. Bull. 39, 1927.
Graham, S. A., *Principles of Forest Entomology.* McGraw-Hill, 1929.
Hebard, Morgan, *The Blattidae of North America North of the Mexican Boundary.* Am. Ent. Soc. Memoir No. 2, 1917.
Hegner, R. W., *Invertebrate Zoölogy.* Macmillan, 1933.
——, *The Parade of the Animal Kingdom.* Macmillan, 1935.
Herms, W. B., *Medical and Veterinary Entomology.* Macmillan, 1923.
Herrick, Glenn W., *Insects Injurious to the Household and Annoying to Man.* Macmillan, 1921.
——, *Manual of Injurious Insects.* Henry Holt, 1925.
Hewitt, C. G., *The House Fly.* Cambridge Univ. Press, 1914.
Hinds, W. E., *Monograph of Thysanoptera of North America.* Proc. U. S. Nat. Mus. Vol. 26, 1902.
Hingston, R. W. G., *Problems of Instinct and Intelligence.* Macmillan, 1929.
Holland, W. J., *The Moth Book.* Doubleday Page, 1922.
——, *The Butterfly Book.* Doubleday, Doran, 1931.
Howard, L. O., *The Insect Book.* Doubleday Page, 1922.
——, *A History of Applied Entomology.* Smithson. Misc. Collect. 84, 1930.
——, *The Insect Menace.* Century, 1931.
Howes, Paul G., *Insect Behavior.* R. G. Badger Co., 1919.
Hungerford, H. B., *The Biology and Ecology of Aquatic and Semi-aquatic Hemiptera.* Kansas Univ. Sci. Bull., Vol. II, No. 17, 1919.
——, *The Nepidae of North America.* Kansas Univ. Sci. Bull., Vol. 14, No. 18, 1922.
Imms, A. D., *A General Textbook of Entomology.* Dutton, 1925.
——, *Recent Advances in Entomology.* Blakiston, 1931.
Kellogg, V. L., *Mallophaga.* Genera Insectorum Fasc. 66, 1908.
——, *American Insects.* Henry Holt, 1908.
Kellogg, V. L., and Doane, R. W., *Economic Zoölogy and Entomology.* Henry Holt, 1915.
Lefroy, H. M., *Manual of Entomology.* Edward Arnold and Co., 1923.
Light, S. F., *Termites and Termite Damage.* Univ. of Calif. Agr. Exp. Sta. Circ. 314, 1929.
Lloyd, J. T., *Biology of North American Caddisfly Larvae.* Lloyd Library, Ent. Series Bull. 21, 1921.
Lochhead, William, *Class Book of Economic Entomology.* Blakiston, 1928.
Lubbock, Sir John, *Ants, Bees, and Wasps.* Dutton, 1929.
Lutz, F. E., *A Fieldbook of Insects.* Putnam, 1921.

Lutz, F. E., *How to Collect and Preserve Insects*. Am. Mus. Leaflet No. 39, 1924.

MacGillivray, A. D., *External Insect Anatomy*. Scarab Co., 1923.

——, *Aquatic Chrysomelidae*. Bull. LXVIII, N. Y. State Mus., 1903.

Maeterlink, M., *The Life of the Bee*. Dodd Mead, 1911.

Matheson, Robert, "The Haliplidae of North America, North of Mexico," *Jour. N. Y. Ent. Soc.*, Vol. 20, 1912.

——, *A Handbook of the Mosquitoes of North America*. C. C. Thomas, 1929.

Matheson, Robert, and Crosby, C. R., "Aquatic Hymenoptera in America," *Ann. Ent. Soc. Am.*, Vol. 5, 1912, pp. 65–71.

Metcalf, C. L., *Syrphidae of Maine*. Maine Agr. Exp. Sta. Bull. 263, 1917.

Metcalf, C. L., and Flint, W. P., *Destructive and Useful Insects*. McGraw-Hill, 1928.

——, *A Textbook of Practical Entomology*. McGraw-Hill, 1932.

——, *Fundamentals of Insect Life*. McGraw-Hill, 1932.

Metcalf, Z. P., and Metcalf, C. L., *A Key to the Principal Orders and Families of Insects* (3d edition pub. by the authors). Raleigh, N. C., 1928.

Miall, L. C., *Natural History of Aquatic Insects*. Macmillan, 1912.

Morgan, Ann H., *Fieldbook of Ponds and Streams*. Putnam, 1930.

Moulton, Dudley, *Synopsis, Catalogue, and Bibliography of North American Thysanoptera*. U. S. Dept. Agric. Bur. Ent. Tech. Ser. Bull. 21, 1911.

Needham, J. G., et al., *Aquatic Insects of New York State*. N. Y. State Mus. Bull. 68, 1903.

Needham, J. G., and Claasen, W. P., *The Plecoptera or Stone-flies of America North of Mexico*. Heckscher Foundation, Cornell University, 1925.

Needham, J. G., and Haywood, H. B., *Handbook of the Dragonflies of North America*. C. C. Thomas, 1929.

Needham, J. G., and Lloyd, J. T., *The Life of Inland Waters*. Comstock Pub. Co., 1916.

Needham, J. G., and Needham, Paul R., *A Guide to the Study of Fresh-water Biology*. Amer. Viewpoint Soc., Inc., 1927.

O'Kane, W. C., *Injurious Insects*. Macmillan, 1912.

Packard, A. S., *Textbook of Entomology*. Macmillan, 1898.

Patton, W. S., and Evans, A. M., *Insects, Ticks, Mites, and Venomous Animals*. Part I, 1929. Part II, 1931. H. R. Grubb and Co., 1931.

Peairs, L. M., *Some Phases of the Relation of Temperature on the Development of Insects*. Agr. Exp. Sta. W. Va. Univ. Bull. 208, 1927.

Pierce, W. D., *Strepsiptera*. Gen. Insect. Fasc. 121, 1911.

——, *The Comparative Morphology of the Order Strepsiptera together with Records and Descriptions of Insects*. Proc. U. S. Nat. Mus., Vol. 54, 1918, pp. 391–501.

——, *Sanitary Entomology*. Richard G. Badger, 1921.

Plath, O. E., *Bumblebees and Their Ways*. Macmillan. 1934.

Reamur, R. A. F., *A Natural History of Ants* (translated by W. M. Wheeler). Knopf, 1926.

Root, A. I., and Root, E. R., *ABC and XYZ of Bee Culture*. A. I. Root Co., 1929.

Sanderson, E. D., and Peairs, L. M., *Insect Pests of Farm, Garden, and Orchard*. John Wiley and Sons, 1921.

Schröder, Christoph, *Handbuch der Entomologie*. Verlag von Gustav Fischer, Jena, 1925.

Slingerland, M. V., and Crosby, C. R., *Manual of Fruit Insects*. Macmillan, 1915.

Smith, J. B., *Economic Entomology*. Lippincott, 1906.

——, *Glossary of Entomology*. Brooklyn Entomological Soc., 1906.

Snodgrass, R. E., *The Anatomy and Physiology of the Honeybee*. McGraw-Hill, 1925.

——, *Morphology and Mechanism of the Insect Thorax*. Smithson. Misc. Collect. 80, 1927.

——, *The Morphology and Evolution of the Insect Head and Its Appendages*. Smithson. Misc. Collect. 81, 1928.

——, *Insects, Their Ways and Means of Living*. Smithson. Misc. Collect. Sci. Ser. 5, 1930.

——, *The Principles of Insect Morphology*. McGraw-Hill, 1935.

Van Duzee, E. P., *Catalogue of Hemiptera of America, North of Mexico*. Univ. Calif. Pub. Ent. 2, 1917.

Van Dyke, E. C., *The Reclassification of the Genera of North American Meloidae*. Univ. Calif. Pub., Vol. 4, No. 12, 1928.

Vierick, H. L., et al., *Hymenoptera of Connecticut*. Conn. Geol. and Nat. Hist. Surv. Bull. 22, 1916.

Walden, B. H., *The Euplexoptera and Orthoptera of Connecticut*. Conn. Geol. and Nat. Hist. Surv. Bull. 16, Part II, 1911.

Ward, H. B., and Whipple, G. C., *Fresh Water Biology*. John Wiley and Sons, 1918.

Wardle, R. A., *The Problems of Applied Entomology*. McGraw-Hill, 1929.

Weed, C. M., *Butterflies* (Little Nature Library). Doubleday Page, 1922.

Weigel, C. A., and Middleton, William, *Insect Enemies of the Flower Garden*. U. S. Dept. Agric., Farmer's Bull. 1495, 1927.

Wellhouse, W. H., *How Insects Live*. Macmillan, 1926.

Wheeler, W. M., *Ants, Their Structure, Development and Behavior*. Columbia Univ. Press, 1910.

——, *Social Life among the Insects*. Harcourt Brace, 1923.

——, *Foibles of Insects and Men*. Knopf, 1926.

——, *Colony Founding among Ants*. Harvard Univ. Press, 1933.

Williston, S. W., *Manual of North American Diptera*. James T. Hathaway, 1908.

In addition to the above, the United States Department of Agriculture has published numerous circulars and bulletins on insects. A list of these can be obtained by writing to the Superintendent of Documents, Government Printing Office, Washington, D. C.

Entomological News, published in Philadelphia, the *Journal of Economic Entomology*, and the *Annals of the Entomological Society of America* contain many current articles of importance. *Biological Abstracts* summarizes all of the current literature of the world and is an excellent reference for scattered publications. The *Zoölogical Record* is also an invaluable source for bibliographical studies.

CHAPTER XV

THE FISHES OF CREEKS, RIVERS, BROOKS, PONDS, AND LAKES

Everyone expects to find fishes in fresh water, whether it be lake, river, creek, or pond; and he usually does find them if other animals or plants are present. There are many kinds of fishes—large and small, long and short, thick and thin, deep and shallow, wide and narrow, toothed and toothless, scaled and scaleless, sharp-nosed and blunt-nosed. Like all other animal groups, the fishes have their habitat preferences; and each species is more or less indigenous to a certain type of environmental situation. In the Great Lakes, with their innumerable bay and shore conditions, as well as stream sources, nearly every kind of northern fresh-water fish is found. Of course there are exceptions since certain kinds inhabit running water only; but even these, having been washed into the lake by flooded streams, are sometimes found.

Within a lake the species are distributed according to depth, currents, temperature, and other conditions. In the shallow waters along the beaches one finds the skip-jack and the minnows; the perch and sunfish forage in the bays where water plants abound; the gar pike or pickerel and the dogfish or bowfin (*Amia calva*) move from place to place, feeding upon the smaller forms among the aquatic vegetation; the catfishes lie on muddy bottoms; the blue pike, bass, sturgeon, white fish, and muskellunge inhabit the deeper waters off shore; the lampreys move about in all situations, looking for unfortunate victims to attack. The lamprey (*Petromyzonidae*) (Plate XVI) with its oral suction disc, which has circles of sharp teeth around it, attaches itself to a fish and sucks its juices. This animal, which is frequently called an eel, has a long, tapering, eel-like body with transverse gill slits along the sides of the neck near the head. The lamprey is not a true eel, nor is it a true fish, although it has some of the characteristics of both eels and fishes. It usually breeds in small streams to which both sexes migrate from large lakes. The eggs are deposited in an excavation in the bottom of the stream and then covered with sand. The

excavations are made by violent movements of the body, the snout and tail being used.

While detailed discussions of all fresh-water fishes would be impossible in a work of this kind, there are certain adaptive features of fishes in general which show fitness to a specialized habitat. Then, too, there are some kinds that inhabit a large section of the United States; and since these are likely to be encountered, many of them are dealt with in this treatise.

That fishes are cold-blooded animals is well known, and their

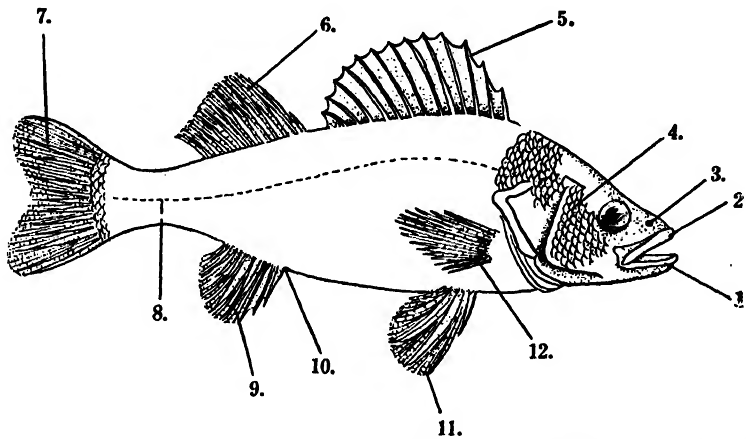


Fig. 159. External features of a fish. 1. Mandible; 2. Maxillary; 3. Nostril; 4. Opercle or gill cover; 5. Anterior dorsal fin; 6. Posterior dorsal fin; 7. Caudal or tail fin; 8. Lateral line; 9. Anal fin; 10. Anus; 11. Ventral fin; 12. Pectoral fin or arm fin. Courtesy Gen. Biol. Supply Co.

temperatures vary with the medium. Some of the northern fishes may be frozen in the ice and yet become active again when the ice thaws. The species which prefer cool water descend to deeper waters in warm weather. However, there are warm-water fishes and cold-water fishes even among our native forms. The brook trout requires comparatively cold water (not above 25°), while sunfishes and bullheads thrive in shallow, sun-beaten ponds. As a rule, fishes are protectively colored; and many of them resemble the bottom of the pond or stream. Others are mottled or striped in such a way as to be inconspicuous among water plants; and in nearly all cases the dorsal surface is dark colored and blends with the coloration of the water. Countershading is characteristic of all fishes, the darker back harmonizing with the dull bottom. The

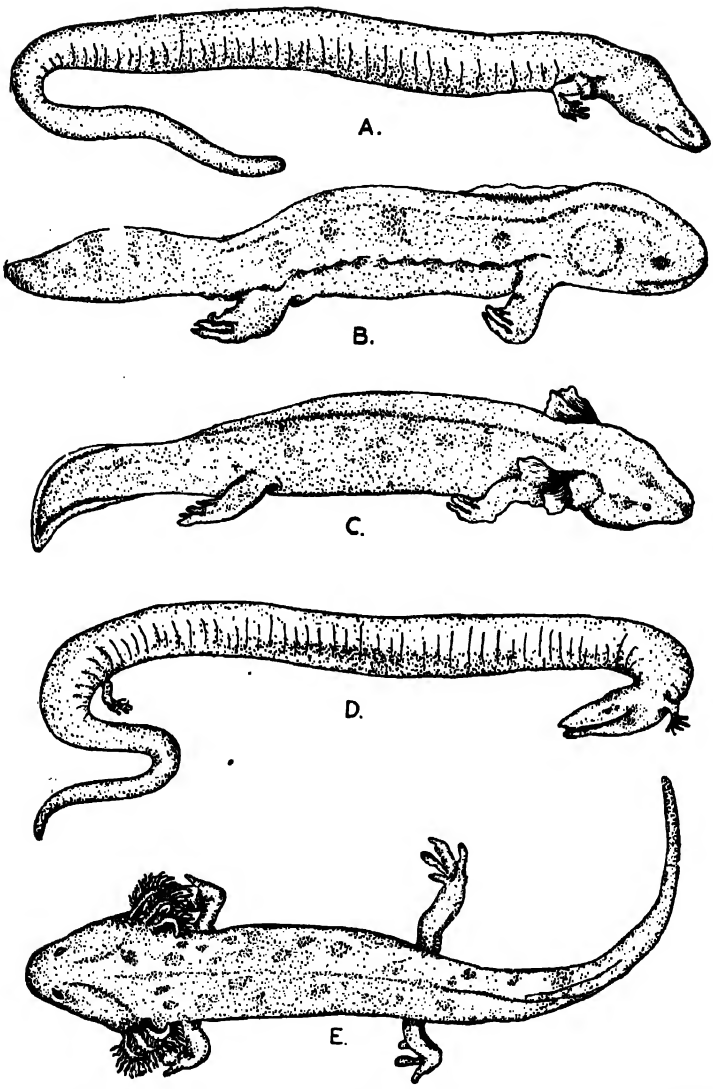


PLATE XIV. Salamanders. A. Siren; B. Hellbender (*Cryptobranchus*); C. Mud puppy or water dog (*Necturus*); D. Congo eel (*Amphiuma*); E. Axolotl (*Ambystoma*). Redrawn by courtesy of the Gen. Biol. Supply Co.

white underside or ventral surface is light so as to be less conspicuous from below when silhouetted against the light at the surface. Many fishes, especially marine species (such as the flounder), even change color so as to be obscure when they move from one kind of situation to another.

The body form of nearly all fishes is spindle-shaped and typifies the almost ideal stream-line form, offering the least possible resisting surface to the pressure of the water. A smooth, slimy covering reduces the friction between the body and the medium. The laterally flattened bodies of many of them, such as sunfishes, make it easier for them to move about among the dense growths of bottom plants. The external features of a fish are shown in Fig. 159.

Fig. 160. The log-perch (*Percina caprodes semifasciata*).

Most fishes possess teeth which occur in several rows. They are of value to the icthyologist in determining species, but to the amateur they are difficult to interpret. The tail or caudal fin is the chief organ of locomotion, the body bending with each movement of the caudal fin so that the flexions of the tail are most efficient. The tail or caudal fin is a variable structure. Sometimes it is a deep "V" as in the minnow (diphycercal), rounded as in the stickleback, and truncated as in the miller's thumb (homocercal). In the sturgeon and shark, the upper fork of the tail is considerably longer than the lower fork (heterocercal). There are three distinct sets of fins in addition to the caudal fin. The pectoral fins are located on the sides, back of the gill plates and just below the median line. They are used as oars only when the fish is moving slowly. They also assist in steering when quick turns are necessary. The ventral fins are on the underside of the body back of the pectorals. In some cases, notably in stream forms such as the darters, these are modified so as to anchor the fish to the bottom and to hold it stationary in a current. Both the pectoral and ventral fins are used primarily for balancing. The armored catfish and

some of the South American gobies use their ventral fins for crawling about on the mud flats at low tide. The flying fishes have greatly enlarged pectoral fins which serve as planes for gliding through the air, and the climbing perch uses its ventral and pectoral fins for climbing. Some tropical fishes have the dorsal

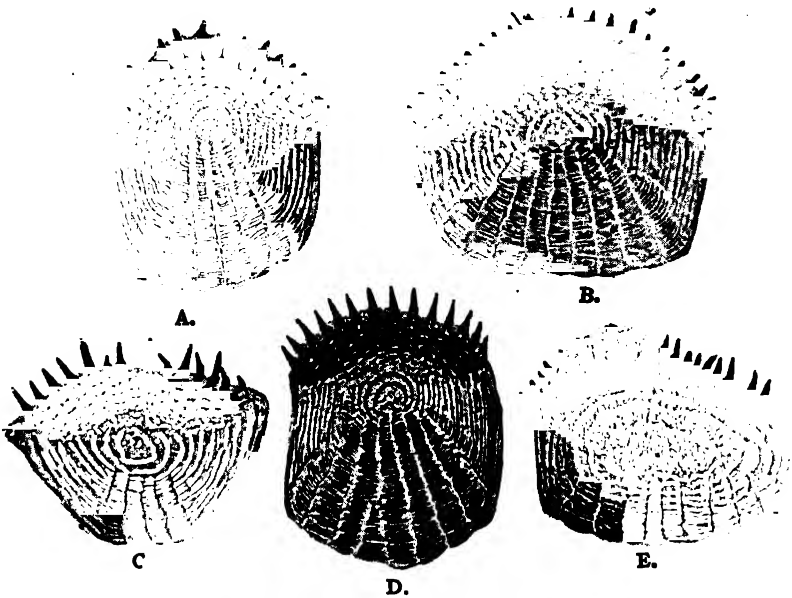


FIG. 161. Types of scales of the log-perch. A. Typical scale of the log-perch from the caudal region of the body; B. Scale taken from the lateral line region about the middle of the body; C. Scale from the opercular region of the body; D. Scale showing two completed annuli and a marginal growth; E. Regenerated scale found on the log-perch. After Will, *Proc. Penn. Acad. Sci.*

fork of the caudal fin elongated into a spine, while the ventral fin in others is similarly extended into a long, single quill. The anal fin is a single fin on the ventral median line before the anus. There are one or two dorsal fins; an anterior spinous fin and in some species, a soft posterior one is present. These, too, are frequently modified as in sailfishes and in sticklebacks, being large and sail-like in the former and having erectile spiny protective rays in the latter. The stinging organ of the catfish is located in the anterior dorsal fin. The dorsal fins serve to offer a vertical surface which, with the water pressure on both sides, helps to keep the fish in an upright position.

These adaptations and others can be tested experimentally in the home or laboratory aquarium. The back is the heaviest part of a fish; and it would, therefore, tend to turn over; but with the aid of the balancing pectorals and the ventral fins, the dorsal fins help to maintain equilibrium by offering an increased vertical surface. If the dorsal fins are clipped off, the animal can maintain an upright position only with an excessive use of the pectorals. Similarly if the pectoral fins are removed, the head sinks, since the anterior end of a fish is heavier than the posterior end. If the pectoral fins are removed from one side, the fish leans toward that side. If all of the pectoral and ventral fins are cut off, the animal turns over on its back. The fact that an injured fish turns on its back is an indication that the mechanical efficiency of the fins is not in itself sufficient to keep the fish in an upright position. Some effort is required on the part of the fish.

Most fishes are covered with scales which overlap each other. The posterior edge of the scale bears a row of teeth or ctenii by which the scale is attached. Scales of this sort are called ctenoid scales. The majority of our fresh-water fishes have ctenoid scales; but the sturgeon has bony plates in the place of scales; a few, the true minnows and the catfishes have no scales at all. The growth of the scales is indicated by a series of concentric rings, and it has recently been proved that the age of a fish can be definitely determined by these rings of growth (Fig. 161).

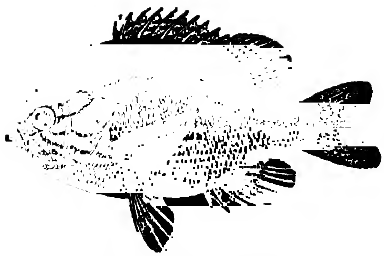
Breathing in fishes is effected by means of pinkish gills which are concealed beneath the opercular or gill covers. The gills are richly supplied with blood capillaries which give to them their pinkish color. An exchange of gases takes place between the blood and the surrounding water through the delicate membranes which enclose the gills, by osmosis. Water is taken in through the mouth of the fish and forced over the gills and discharged through the opercula. In purchasing fish in markets, the freshness can be judged by the gills, which are light pink or red if the fish has been recently caught and dark red if it has been out of the water for some time. The parasitic glochidia (larvae) of mussels and also copepod crustaceans are frequently attached to the gills.

One of the most remarkable organs of fishes is the swim bladder which most of our species possess. This rather large, hollow, transparent, dirigible-like, air-filled bladder is an outgrowth of the alimentary canal with which it is connected in many species such

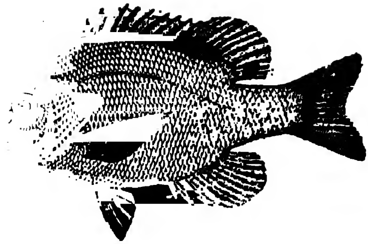
as the carp, salmon, and eel; but its connection has been lost in the bass, perch, and cod. The swim bladder is situated between the alimentary tract and the vertebral column, as a rule. The functions of the bladder are several, its chief function being suggested by its name. It serves as a hydrostatic organ; and by changing the specific gravity of the fish, it enables the animal to sink, float, or remain suspended in the water at any depth. In some species it also serves as a storage for a reserve supply of air which can be drawn upon under unfavorable conditions. It has been shown that an excess of carbon dioxide in the water causes a surplus in the swim bladder, and the animal is automatically forced to the surface where the oxygen supply is the most abundant. Recent investigations have shown that the swim bladder is a sound-producing organ in some fishes, while it has long been supposed to function as an accessory auditory organ in other species.

The eggs of some fresh-water fishes are heavy and sink to the bottom where they lodge among the gravel (salmon, trout, suckers, some minnows, and lampreys). In catfishes and miller's thumb, the eggs are cohesive, being held together and to objects by a sticky covering. The goldfish lays sticky eggs that are attached singly to plants. The perch and gar pike suspend their strings of eggs on plants. The eggs of sticklebacks are attached to the nest by adhesive, mushroom-shaped processes; and the skip-jack eggs have long filaments on them for attachment to plants. Some oceanic fishes produce floating eggs. Some South American catfishes carry their eggs in their mouths, and others carry them attached to the ventral body surface. Some African and South American fishes carry their eggs and young in their mouths and gill chambers, and the blind fishes of North America keep their eggs in the gill chambers until they hatch. There are many fishes in the world that retain their eggs until the young are hatched and even until the yolk is completely absorbed by the young, growing fish. Living young are thus produced. A number of southern cyprinodont fishes in the United States have this habit.

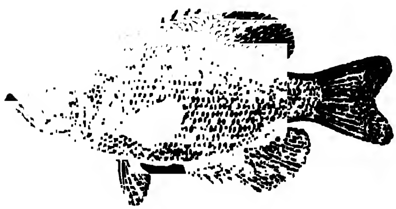
While there are many fishes which bring forth living young, all of our northern, native species are oviparous and produce eggs. The eggs of fishes are usually fertilized by the males after the females have deposited them. The egg laying process is called spawning, and the process of egg laying is often accompanied by violent and interesting behavior. The actions of the sexes are



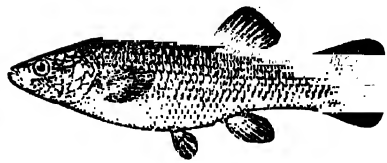
Common Sunfish



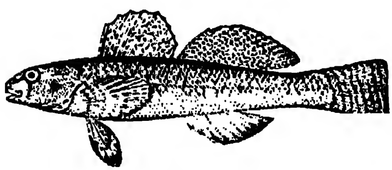
Bluegill Sunfish



Crappie

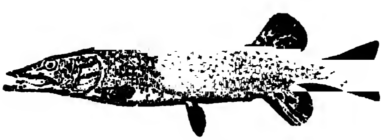


Common Killifish



Tessellated Darter

Blob or Miller's Thumb



Pickerel or Grass Pike

Muskellunge

PLATE XV. Fresh-water fishes. From Report Penn. Board of Fish Commissioners.

quite variable in the different species. The male, however, usually follows the female closely, frequently going through weird dances while the female is laying the eggs. After the eggs have been laid, the male swims back and forth over them, depositing the milt containing the spermatozoa on them. In the commercial propagation of fishes, the fishes are taken just before they spawn. The females are stripped of their eggs which are removed by gently squeezing them through the anal aperture. The milt of the males is secured in a similar manner. The eggs are placed in a tub, and the milt is poured over them. The eggs are then stirred so as to thoroughly mix the eggs and the milt and to insure the fertilization of each egg. The tail of a fish is usually used as a stirrer. In this way a much greater percentage of the eggs are fertilized than would ordinarily be the case in nature. It is therefore an improvement over nature's way.

Since there are currents (and enemies) in all bodies of water, every species of fish attempts to establish some definite nest in which to place the eggs and thus prevent their being scattered or washed into unfavorable places. By keeping the eggs together in a nest they can be more easily concealed or guarded. These nests vary with the species and will be discussed in connection with the kinds of fishes that are included here.

The senses of fishes are not entirely understood. The sense of sight is well developed, and the pupils of the eyes are large since they live where light is not abundant, as a rule. The eyes are located in such position as to make the scope of vision large. In free-swimming forms the eyes are on the sides of the head. In bottom species they are nearer the top of the head. In a tropical fish that lives at the surface of the water, the eyes are divided into two pairs—one pair for looking down through the water, and the other for looking upward through the air. Fishes are sensitive to light through their body surfaces, also, because of the presence of light receptors in the skin. Among fishes there are diurnal and nocturnal kinds. The latter rest under objects such as stones, logs, and ledges during the day in order to escape the light. Other species are active during the day. A pair of nostrils is present on all fishes, and the sense of smell is used in discriminating among foods to some extent. It is doubtful if the sense of taste is highly developed since fishes usually capture and swallow their food quickly, although they frequently spit out food which they some-

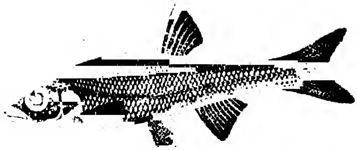
times take by their usual quick, indiscriminatory, gulping movements.

There is no doubt that fishes hear. In fact they are very sensitive to sounds. In a large number of our fresh-water fishes the air bladder is connected with the ear by a chain of bony ossicles. In others the swim bladder comes in contact with the skin just behind the head. The intercostal muscles are not developed at this place, and a simple tympanum is thus formed. Through this sounds are perceived. Vibrations of lower frequency are perceived through the so-called lateral line organs, as indicated elsewhere.

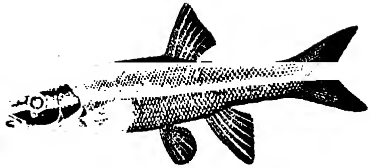
The food of fishes is variable. Some eat only active, living animals, while others are scavengers and feed upon all sorts of organic material. Many of them prey upon other fishes, and some of these will even eat birds and mice. Sharks, barracudas, and perani will even attack man. Some species feed at the surface where they devour the minute plancton organisms, and some of them capture floating insects. Some of these will leap from the water to capture insects flying over it. The catfishes and suckers are bottom feeders and never rise for food as do the bass and trout which range through vertical depths in search of food. Worms, crustaceans, insects and their larvae, mollusks, frogs and tadpoles, salamanders, other fishes, and waste matters constitute the food of the various fresh-water fishes. The young of most species have different feeding habits from the adults of the same species. The minute crustacea, such as cladocerans, ostracods, amphipods, and copepods, serve as the food of most young fishes. A number of them devour diatoms.

It has already been stated that certain kinds of fishes are indigenous to still water while others can only be found in streams. Among the more common pond fishes are the bullhead, catfish, or horned pout (*Ameiurus nebulosus*); the common sunfish (*Eupomotis gibbosus*); and in comparatively fresh ponds, the stickleback (*Eucalia inconstans*). In the cold streams the trout is characteristic. In small, rapid creeks, the minnows (blunt-nosed dace, horned dace, black-nosed dace), shiners, darters (rainbow darter, johnny darter), and the blob or miller's thumb are the ones usually found. In the larger creeks and rivers are catfish, suckers, bass, carp, perch, muskellunge, and pickerel (Plates XV XVI, XVII, XVIII, XIX).

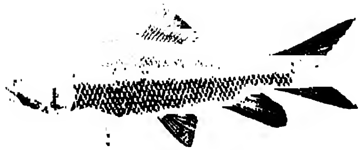
The sunfish (family *Centrachidae*) constructs a nest among the weeds when these are present or makes a depression in the sand



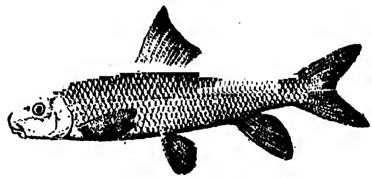
Redfin



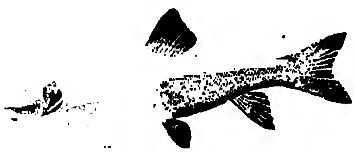
Black-Nosed Dace



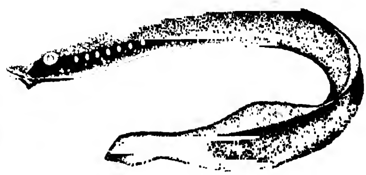
Big-Jawed Sucker



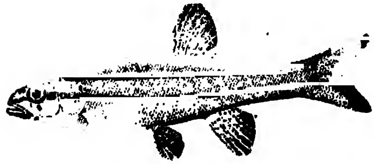
Red Horse Sucker



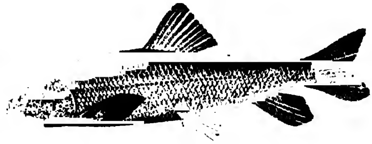
Northern Sucker



Brook Lamprey



Red-Bellied Dace



Stone Toter

PLATE XVI. Some common fresh-water fishes. From Report Penn. Board of Fish Commissioners.

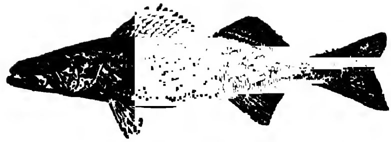
with its snout and tail. A sandy-bottomed pond in summer will usually reveal numerous circular depressions in which the eggs are laid. The male stands guard over the nest and drives away all other fish which venture too close. The common sunfish, which is the commonest of the sunfishes, has a green back; the sides are flecked with blue. Dull, faint, olive-green cross bars are visible on the sides, and there is a bright red spot on the gill cover near its edge. The ventral fins of the male are black, while those of the female are yellowish. Other species of sunfishes with habitats somewhat similar to those of the common sunfish are the long-eared sunfish (*Xenotis megalotis*); red-bellied sunfish (*Lepomis auritis*); the green sunfish (*Apomotis cyanellus*); the bluegill (*Helioperca incisor*); and the rock bass (*Ambloplites rupestris*), which is very common in the Allegheny Mountain section.

The male small-mouth black bass (family *Centrachidae*) builds the nest alone and then drives the female away after she has deposited the eggs in it. There are two kinds of black bass—the large-mouth and the small-mouth. Both are excellent game fishes. They are both quite generally distributed; and they abound in lakes, rivers, fresh ponds, and creeks.

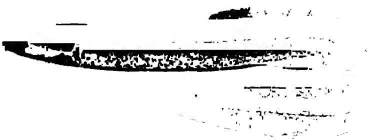
Contrary to their names, neither species is black. They are both greenish on the back and sides, and the intensity of color varies considerably. Indistinct cross markings of black are often present. The small-mouth does have a smaller mouth than the large-mouth, and the angles of its jaws do not extend back of the eyes as they do in the large mouth. The black bass feeds upon moving animals such as crayfish, worms, frogs, and other fishes. The large-mouth bass attains a length of thirty inches and sometimes weighs eight pounds. The small-mouth bass seldom reaches more than twenty-four inches.

The yellow perch (*Perca flavescens*—family *Percidae*) is one of the most abundant of eastern fishes, being found in ponds, lakes, and streams almost everywhere. Its eggs are laid in strings which are suspended from water plants among which it is commonly found. The perch may easily be recognized by the bright yellow of its sides which have dorso-ventral bars of black, and by the orange-colored fins. The back is a yellowish green. The cross bars on the sides are of protective value in that they resemble shadows cast by the stems of water plants. When resting, the perch usually takes advantage of its protective coloration by remaining motion-

Horned Chub



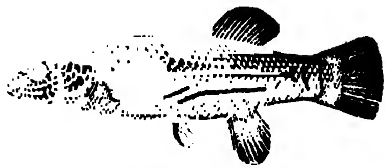
Blue Pike



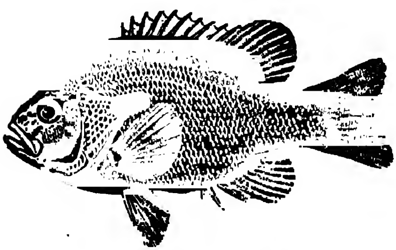
Eel

Log-Perch

Common Sturgeon



Striped Killifish



Long-Eared Sunfish

Common Catfish

PLATE XVII. Fresh-water fishes. From Report Penn. Board of Fish Commissioners.

less with its side against the stem of a plant. The perch seldom reaches a foot in length.

The stickleback (family *Gasterosteidae*) is a quick-moving, pugnacious little fish which follows other fishes in the aquarium and keeps nipping off their fins until they are rendered almost helpless. Minnows and small sunfish lead a miserable existence in the tank when sticklebacks are present. The stickleback is seldom more than four inches long. The anterior dorsal fin has hard, sharp, horny rays which can be locked in an erect position and which protect the fish from being eaten by birds and larger fishes. The number of rays in the dorsal fin is variable according to species, being two, three, nine, or fifteen in the more common kinds.

The stickleback is yellowish green on the back and greenish yellow on the sides. The underside is a feeble yellow. The stickleback makes a rounded nest composed of the twisted stems of plants glued together by a secretion from the kidney of the male. The nest is usually attached to submerged plants and above the bottom. The nest is about an inch in diameter, and the entrance is on the side. The male constructs the nest; and when it is completed, the female enters. When the female emerges after laying the eggs, the male goes in and fertilizes them by discharging the seminal fluid on them by swimming back and forth over them. After fertilizing the eggs, the male emerges; and he assumes responsibility for the safety of the eggs and young. He guards the nest by swimming around it just as he did while it was occupied by the female. During this time the male is very pugnacious, and he does not allow any other fish to get near the nest.

The bullhead, catfish, or horned pout (family *Siluridae*) is a bottom feeder, inhabiting ponds, streams, and lakes with muddy bottoms. It is slimy and scaleless, and it is easily recognized by the long barbels or whiskers around the mouth. The barbels are tactile structures which are highly specialized for recording contacts. Catfishes must be handled with caution, as most fishermen know. They can inflict poisonous and painful lacerations with their stings which are the front edges of their pectoral fins. There are several species of catfishes, the smallest being the mad tom (*Schilbeodes gyrinus*) which has a length of three inches, and the black bullhead which attains a length of about six inches. The bodies are wide and somewhat flattened, and the heads are blunt

and rounded. The mouth is quite large and sub-terminally located. Certain tropical catfishes weigh considerably more than a hundred pounds, and the Mississippi channel catfish weighs upwards of fifty pounds. The pond species attach their yellowish eggs in masses to submerged objects; and when hatched, the young frequently remain together in a compact, rounded aggregation which moves slowly en masse. If the coal-black young are separated, they immediately migrate back together again. Sometimes nests are made; these are shallow excavations in the bottom.

In addition to the perch and the wall-eyed pike, the perch family (*Percidae*) contains some of our most interesting and lesser-known fresh-water fishes. The darters,[1] or "stone gliders," belong here. All of them are inhabitants of rapidly flowing creeks where they lurk under or among the stones. Their movements are very swift, as the collector of stream life knows. When a stone is lifted, the darter makes a rapid dart and disappears under a nearby stone. It seldom swims more than a few feet in a single journey. The darter lives on the bottom where its sub-inferior mouth and slightly decurved snout are adapted to bottom feeding. Its large, well-developed, and expanded ventral and anal fins hold it in position on the bottom against the flow of current. There are several species of darters, the commonest being the Johnny darter which is slightly less than three inches in length. It is colored a pale olive-brown. The rainbow darter is much lighter in color, and its sides reflect a rainbow hue in bright light. All of the numerous species of darters are confined to the bottoms of creeks and cool lakes, and they are never seen suspended in the water. Some of them live in sandy bottoms where certain species bury themselves in the sand, leaving their protruding eyes exposed. Some species attach their eggs to the upper side of rocks, although most of them attach their eggs to pebbles in shallow excavations.

The blob or miller's thumb (*Cottus bairdii*) is also an inhabitant of small, cool brooks where it lurks under stones during the day. When resting on the bottom, the blob resembles a brownish tadpole. The head is extremely large for a fish of five inches; and it is flattened like a miller's thumb—hence its name. Unlike the darters, the blob lacks scales; but there are spiny processes behind the front fins, and the head is rough and almost warty. Jordan calls the

[1] The darters have recently been placed in the family *Etheosteidae*, where they properly belong.

miller's thumb a blob or sculpin and includes it in the family *Cottidae.* The salmon-pink eggs, which are also large for a small fish, are laid in grape-like clusters on the undersides of stones in swift water. Usually the male loiters in the vicinity of the eggs until the young are born.

The minnows belong to the family *Cyprinidae,* which also includes the carp and goldfish. There are many species of minnows scattered throughout North America, and all of them are scaly. They frequently have black spots on their gills and skin and sometimes in the fins. These are embedded parasitic larvae of the mussels, and they must not be confused with color markings. The common types of minnows are: the black-nosed dace (*Rhinicthys atronasus*), which is a small minnow about two and one-half inches long. It inhabits the smaller streams. It is marked with a broad, black band which extends from the tip of the snout along the sides of the body to the tail, separating the dull olive-green of the back from the silvery white underside. The jaws are short, giving the head a blunt appearance.

The horned dace (*Semotilis atromaculatus*) is a stream form associated with the black-nosed dace. It is a dusky color with an almost bluish tinge and conspicuously marked with a large black spot at the base of the dorsal fin. In the males, this spot is usually bordered with red. During the breeding season, which extends from May to July, the heads of males are orange-colored and covered with little, horn-like growths called "pearl organs." The male builds the nest which is a shallow pit walled with small stones. The stones are pushed into position with the head, and the nest is usually located in the ripples. When the nest is finished, the female enters, lays her eggs, and leaves. The male stands guard until the eggs hatch. This species is sometimes called the riffle chub, and it may reach a maximum length of twelve inches, although individuals of this size are extremely rare.

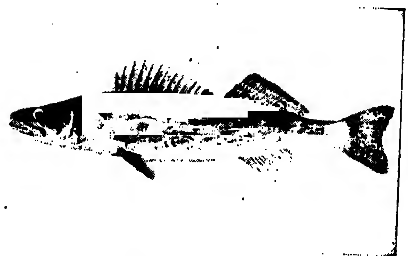
The blunt-nosed minnow (*Hyborynchus notatus*) is seldom more than four inches long. It is olive-green on the back and bluish on the sides. The underside is silvery. There is a black spot at the base of the dorsal fin and another at the base of the caudal fin. This minnow is also called a chub.

The shiner or redfin (*Notropis cornutus*) is an abundant species in most small streams. It is a deep olive-green on the entire back and a shining silvery white below and on the sides. Its

White Perch

Calico Bass

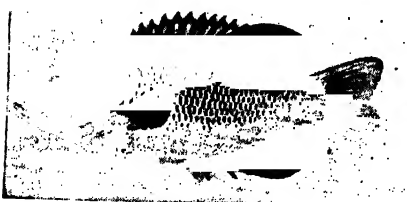
Black-Banded Sunfish



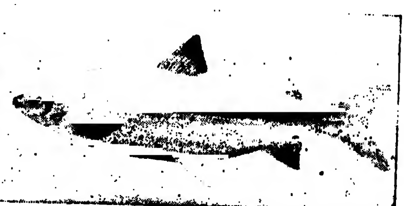
Pike Perch

Goldfish

Yellow Perch



Rock Bass



Whitefish (Lake Erie)

PLATE XVIII. Common fishes. From Report Penn. Board of Fish Commissioners.

sides glisten in the sunlight. In the breeding season the fins of males are bordered with red, and the back is an iridescent blue. The sides reflect rainbow colors in bright light. The species is from five to eight inches long. It breeds in May or June, and the nest is a hollow basin made in the middle of the stream.

The red-bellied dace (*Chrosomus erythogaster*) is the most highly colored minnow in the United States. The belly and the bases of the vertical fins of males are bright red during the spring mating season. This species is abundant west of the Allegheny Mountains as far as Colorado.

Among the *Cyprinidae* there is a curious fish known as the stone roller (*Campostoma anomalum*). It is quite generally distributed over the United States from New York to Wyoming and southward to the Rio Grande River. It is brownish above with a bronze luster, and the scales are slightly mottled. There is a black vertical bar back of the opercle. The dorsal and anal fins each have a dusky bar across the middle. In the spring, the fins of the males are orange in color, and the females have rounded tubercles on the head and body. The species is from four to eight inches in length, and it inhabits small streams where it rests among the pebbles on the bottom.

The chub or fallfish (*Leucosomus corporalis*) is the largest member of the *Cyprinidae* east of the Rocky Mountains. It is an inhabitant of the ripples in from small to moderate-sized streams. The single dorsal fin is situated midway between the nostrils and the tail or caudal fin. The fins are plain, and the dorsal surface of the body is bluish brown above while the sides are silvery. The species attains a maximum length of eighteen inches, although they usually average five or six inches. It is an edible species familiar to the average country boy who fishes in the shallow creeks.

The brook trout, speckled trout, or charr (*Salvelinus fontinalis*) belongs to the salmon family (*Salmonidae*). It is one of the most beautiful of American fishes, and it has quite a reputation as a game fish. The trout is almost scaleless in appearance although it is entirely covered with fine embedded and invisible scales. The body is a mottled olive green, covered with spots of gray and scarlet. The underside is reddish in males, and the fins are mottled or barred; the first ray of the ventral fins is orange.

The trout is an inhabitant of clear, cold streams only. It pre-

fers shaded sections where it lurks under rocks, darting out rapidly to capture a floating insect or a swimming larva. The food of the trout consists of caddis fly larvae which it extracts from the cases, stonefly and May fly larvae, and other aquatic insects. The caudal fin is forked in young trout but lunate in adults. The species attains a length of twenty-four inches. In streams which become considerably warmer in the summertime, the brown trout has been introduced. The brown trout will withstand higher temperatures and a lower oxygen content than will the brook trout.

The white sucker (family *Catostomidae*) is a common fish in rivers, and its food value is underrated. It is readily identified by its round, sucking mouth which is located well under the head. The sucker has the usual stream colors; but in the breeding season the male has rose-colored fins. In some species the bodies are covered with small tubercles in the mating season. Suckers are bottom feeders, and they attain a length of 18 inches. No teeth are present. There are numerous species of suckers in the United States, including the buffalo fish of the Mississippi valley which weigh up to 50 pounds, the carp suckers, and the fine-sealed suckers.

The common gar pike or long-nosed pike (*Lepisostetus osseus*) is an abundant resident of lakes and large streams throughout the eastern United States, ranging as far south as Louisiana and Florida. It is the bane of sportsmen and commercial fishermen because it destroys many game fishes, especially in their early stages. The gar has a long, narrow snout which is more than twice the length of the head. It is a yellowish olive color, with the vertical fins and the posterior part of the body covered with black spots, although the coloration is somewhat variable. There is a short-nosed gar which differs from the common gar in having a much shorter snout. The bodies of both are sub-cylindrical and slender. Both species are covered with bony scales almost like those of the ganoid fishes (sturgeon). They belong to the family *Lepisosteidae*. A huge gar known as the alligator gar attains a length of almost ten feet. It is covered with large, enameled scales. It is found in the Mississippi valley as far north as southern Ohio. All of the gars are inedible.

Another worthless fish as far as food is concerned is the bowfin or dogfish (*Amia calva*) which is abundant in many sections of the United States. It is an enemy of valuable fishes, but in many respects it is one of our most interesting species because of its

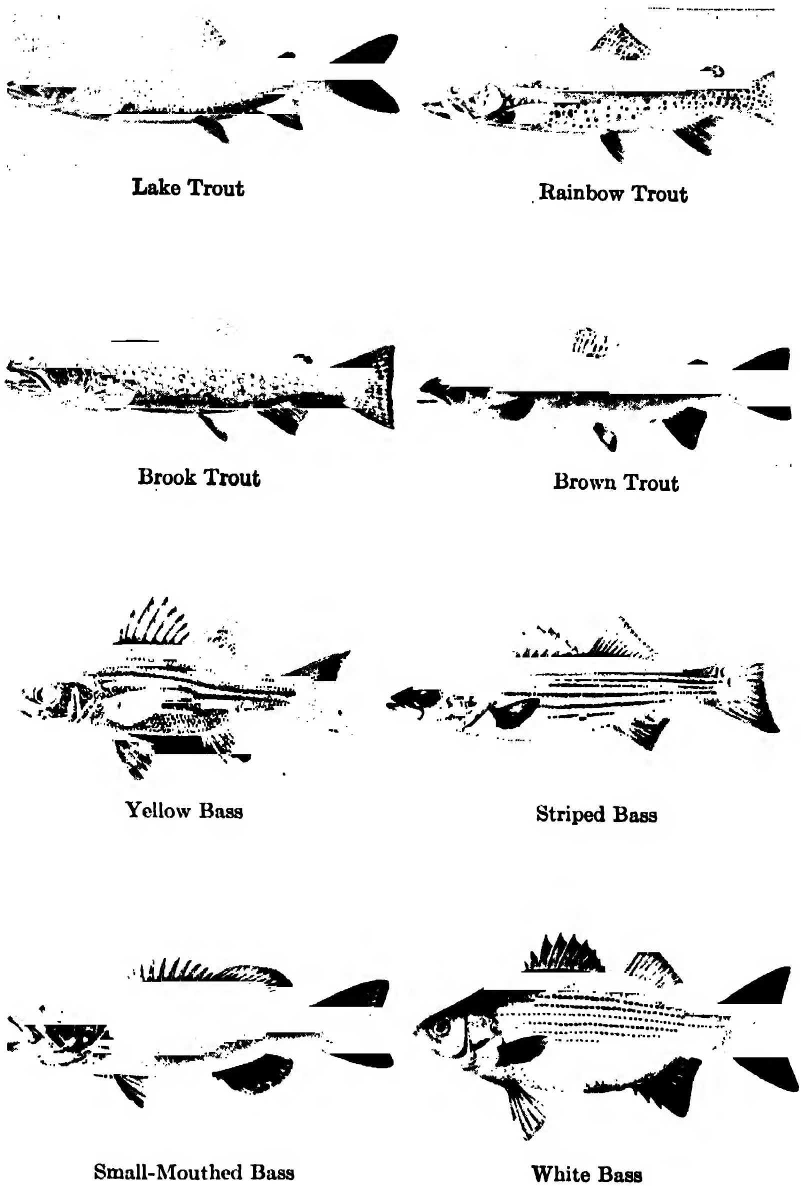


Plate XIX. Common fresh-water fishes. From Report Penn. Board of Fish Commissioners.

primitive nature. The females are larger than the males and may attain a length of 30 inches. The males seldom exceed 20 inches. The bowfin is dark, brownish olive with black spots under the head. There is a large, black spot on either side near the base of the caudal fin. Greenish lines are also visible on the body. The head is subconical and covered with a bony helmet. The body scales are hard and thick. The bowfin inhabits swamps, lakes, and rivers. It belongs to the family *Amiidae* in which there is but a single species. The flesh is inedible.

The common pickerel or chain pickerel (*Esox niger*) belongs to the family (*Esocidae*) in which the muskellunge is also included. The pickerel is an inhabitant of streams, lakes, and large ponds throughout the eastern section of the United States. It lurks among the weeds and water lilies; and in some places it is called the grass pike. It is an admixture of green and brown with a yellowish cast on the sides and back; but it is somewhat paler beneath. The body is long and slender in comparison with the short, thick, and deep body of the bass with which it is frequently associated. The lower jaw protrudes slightly, giving the species a melancholy appearance. The pickerel is an excellent game fish, and it feeds mainly upon other fish and frogs. The maximum length of the pickerel is slightly more than two feet.

The muskellunge (*Esox masquinongy*) is the largest game fish in fresh water, with the exception of the sturgeon which is rather scarce. It attains a length of four to eight feet or more and may weigh up to a hundred pounds. The lower jaw protrudes a little more than in the pickerel which it resembles in color. The "muskie" is a favorite with the fishermen of northeastern United States, although its distribution is somewhat limited.

The true eel (family *Anguillidae*) is a snake-like fish which lives in fresh water up to the time of breeding, when it migrates into salt water from which the adults never return. The migration of eels constitutes one of nature's most spectacular and enigmatical phenomena. When full grown, a fresh-water eel is about three feet long as a rule, although the female may reach a length of five feet. It lives on the bottom of ponds and streams where it feeds upon almost anything from smaller fish to waste matter. After six or eight years in fresh water, the adult eels migrate down stream and into the ocean where they go directly to the warm seas in the region of the Virgin Islands. In the vicinity of

these islands mating takes place. The eggs are spawned in deep waters, and they hatch into transparent, floating larvae which drift near the surface for almost a year. Then they get caught in the Gulf Stream and are carried northward. As they approach the coastal regions of North America they develop the true eel characters; and the young ones, measuring only a few inches, swim into the mouths of the fresh-water streams and begin their inland migrations, traveling at night and resting during the day. Only the females make the journey to the headwaters, and they are found at an altitude of 8000 feet in Colorado. The males remain in the lower sections of the streams. After the normal period in fresh water, the oceanic migration starts all over again. The adults probably die after mating. Even the European eels migrate to the West Indies to breed.

State and Federal Bureaus of Fisheries have published numerous bulletins which deal with the various species of fishes, especially the game and commercial kinds. The manufacturers of fishing equipment and artificial bait also have interesting circulars and handbooks which give the species and the habits of many kinds of fish throughout the country. From these sources the student can ascertain additional data about the fishes indigenous to the region in which he lives.

The characters by which fishes are identified, in addition to size, teeth, and coloration, include: the number of fins; number of rays in the fins; size of the eyes; length and depth of the head; nature of the scales (ctenoid, etc.); attachment of the scales; the number of scales above and below the lateral line; the number of scales in the dorsal row between the dorsal fin and the head; length of the maxillary and mandible; and internal characters such as the length of the intestinal tract; skeleton; swim bladder; etc.

BIBLIOGRAPHY

Fishes

Coker, R. E., *Fishes*. Documents 896, 911, 936, Rep. U. S. Bur. Fisheries, 1919 to 1920.

——, *Studies of the Common Fishes of the Mississippi River at Keokuk*. U. S. Bur. Fisheries Doc. 1072, 1930.

Comstock, A. B., *Handbook of Nature Study*. Comstock Pub. Co., 1911.

Creaser, C. W., *The Structure and Growth of the Scales of Fishes, etc.* Univ. of Mich. Zoöl. Publ. 17, 1926.

Daniel, J. F., *The Elasmobranch Fishes.* Univ. of Calif. Press, 1922.

Eifrig, C. W. G., *Our Great Outdoors.* Rand McNally, 1930.

Forbes, S. A., *On the General and Interior Distribution of Illinois Fishes.* Bull. Ill. State Lab. Nat. Hist., Vol. VII, Art. III, 1909.

Forbes, S. A., and Richardson, R. E., *The Fishes of Illinois.* Bull. Ill. State Lab. Nat. Hist. III, 1908.

Gill, T., *Parental Care among Freshwater Fishes.* Smithson. Inst. Rept. for 1905, 1907.

Goldsborough, E. L., and Clark, H. W., *Fishes of West Virginia.* Bull. U. S. Bur. Fish., Vol. XXVII, 1908, pp. 29–39.

Goode, A. M., *American Fishes.* C. Page and Co., 1926.

Hankinson, T. L., *Walnut Lake.* Rep. Mich. Biol. and Geol. Surv., 1907.

Hegner, R. W., *The Parade of the Animal Kingdom.* Macmillan, 1935.

Hildebrand, S. F., and Meek, S. E., *Synoptic List of the Fishes Known to Occur within Fifty Miles of Chicago.* Field Mus. Nat. Hist. Pub. 142, Zoöl. Series 7, No. 9, 1910.

Holder, C. E., *Big Game Fishes of the United States.* Macmillan, 1903.

Hubbs, C. L., *Studies of the Fishes of the Order Cyprinodontes.* Univ. Mich. Mus. Zoöl. Misc. Pubs. 13, 16, 1924.

——, *A Check List of the Fishes of the Great Lakes and Tributary Waters, with Keys.* Univ. Mich. Mus. Zoöl. Misc. Pub. 15, 1926.

Jordan, D. S., *A Guide to the Study of Fishes*, 2 vols. Henry Holt, 1905.

——, *A Manual of the Vertebrates.* World Book Co., 1929.

Jordan, D. S., and Brayton, A. W., *Fishes of the United States.* U. S. Nat. Mus. Bulls. 9–12, 1877 to 1878.

Jordan, D. S., and Everman, W. E., *The Fishes of Middle and North America.* U. S. Nat. Mus. Bulls., 1896.

——, *American Food and Game Fishes.* Doubleday Page, 1902.

Juday, C., and Wagner, G., *Dissolved Oxygen as a Factor in the Distribution of Fishes.* Wis. Acad. Sci. Arts and Letters XVI, Part 1, 1908.

Koelz, W., *Coregonid Fishes of the Great Lakes.* Bull. U. S. Bur. Fish. 43, 1929.

Kyle, H. M., *The Biology of Fishes.* Macmillan, 1926.

Lyon, E. P., "Rheotropism in Fishes," *Am. Jour. Phys.*, Vol. XII, 1904, pp. 149–161.

Mellen, Ida M., *The Young Folks' Book of Fishes.* Dodd Mead, 1927.

Morgan, Ann, *Field Book of Ponds and Streams.* Putnam, 1930.

Needham, J. G., and Lloyd, J. T., *The Life of Inland Waters.* Comstock Pub. Co., 1916.

Needham, J. G., and Needham, P. R., *A Guide to Freshwater Biology.* Amer. Viewpoint Soc., 1927.

Osburn, R. C., *The Fishes of Ohio.* Press of Spahr and Glenn, 1901.
Osburn, R. C., et al., *A Revised List of the Fishes of Ohio.* Ohio State Univ. Zoöl. Contr. 102, 1930.
Pearse, A. S., *Animal Ecology.* McGraw-Hill, 1926.
——, "The Migration of Animals from the Ocean into Freshwater and Land Habitats," *Amer. Nat.*, Vol. LXI, Sept.-Oct., 1927.
Pratt, H. S., *A Manual of the Common Land and Fresh-water Vertebrates of the United States.* Blakiston, 1923.
Reeves, C. D., *The Breeding Habits of the Rainbow Darter.* Biol. Bull. XIV, No. 35, 1907.
Reighard, Jacob, *Methods of Studying the Habits of Fishes with an Account of the Breeding Habits of the Horned Dace.* Bull. U. S. Bur. Fish. XXVIII, No. 111, 1910, pp. 2-36.
Reynolds, S. H., *The Vertebrate Skeleton.* Cambridge Univ. Press, 1913.
Roule, Louis, *Fishes, Their Journeys and Migrations.* W. W. Norton Co., 1933.
Shelford, V. E., *Pond Fishes.* Biol. Bull. XXI, 1911.
——, *Stream Fishes and the Method of Physiographic Analysis.* Biol. Bull. XXI, 1911.
——, *Animal Communities in Temperate America.* Univ. of Chicago Press, 1913.
Smith, B. G., *The Spawning Habits of Chrosomus erythogaster.* Biol. Bull. XV, 1908, pp. 9-18.
Ward, H. B., and Whipple, G. C., *Freshwater Biology.* John Wiley and Sons, 1918.

CHAPTER XVI

THE AMPHIBIANS: FROGS, TOADS, AND SALAMANDERS

The class Amphibia includes the frogs, toads, newts, and salamanders. They are cold-blooded (poikilothermal) vertebrates, many of which spend a portion of their lives in water and the other portion on land; hence their name, Amphibia, which means double life. The amphibians differ from the reptiles in that the great majority of them are hatched in the water or in very moist places, and all of them breathe by means of gills in their larval stages. Some adults have lungs and some retain gills. Others breathe entirely through the skin. Their skin is usually smooth and slimy, although certain forms such as the toads have rough, dry skin. Nearly all of them, however, have mucous glands in the skin which keep it moist; and only one group, the Caecilians, shows any evidence of scales. In these the scales are embedded in the skin and can be seen only after careful dissection. The Caecilians are primitive amphibians which suggest one of the intermediate stages in the derivation of the Amphibia from the fishes. In the salamanders and frogs, respiration is largely effected through the skin.

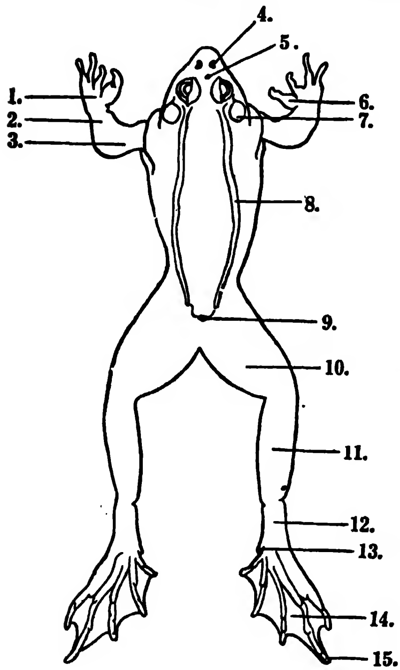


FIG. 162. External features of a frog. 1. Hand; 2. Forearm; 3. Upper arm; 4. External nares; 5. Brow spot; 6. Inner finger; 7. Tympanic membrane; 8. Plica or dorso-lateral dermal skin folds; 9. Anus; 10. Thigh; 11. Shank; 12. Foot; 13. Prehallux; 14. Web; 15. Toe. Courtesy Gen. Biol. Supply Co.

The Amphibia are intermediate between the fishes and reptiles. Their remarkable metamorphoses, in which the transition from truly aquatic to terrestrial adaptations can be seen, make their life histories extremely interesting. These transformations reveal one of the courses of evolution. In a few short weeks, from the hatching of the egg into the gilled, fish-like larva until lungs and legs have developed, we can see the recapitulation of thousands of years of phylogenetic progress.

The Amphibia are grouped into two principal orders: (1) *Caudata,* which includes the tailed forms such as newts and salamanders; and (2) *Salienta,* into which are grouped the frogs and toads, which have short, stout, tailless bodies and long hind legs.

The Salamanders. There are seven families of tailed amphibians in the United States as follows:

(1) *Cryptobranchidae,* with one American representative, the hellbender (*Cryptobranchus alleganiensis*) which has a rather wide but somewhat discontinuous distribution throughout eastern United States.

(2) *Ambystomidae,* with four genera and 14 species, among them the tiger salamander, marbled salamander, spotted salamander, and Jefferson's salamander.

(3) *Salamandridae,* or *Pleurodelidae,* the newts, with one genus and four species.

(4) *Amphiumidae,* the "Congo eel" of the Gulf coast and Mississippi valley; two species (Plate XIV, Fig. D).

(5) *Plethodontidae,* the lungless salamanders, including the common dusky salamander and other very common forms.

(6) *Proteidae,* which includes the "water dog" or "mud puppy" (*Necturus maculosus*).

(7) *Sirenidae,* two genera and three species of permanent larvae with anterior appendages only. The sirens (Plate XIV, Fig. A) of the Southwest are the only American members of this family.

The newts and salamanders constitute a large and somewhat commonly found group of the Amphibia. These are lizard-like or alligator-like in appearance, having four short legs and prominent tails. While most of them lay their eggs in fresh water, there are some which deposit their eggs on land under logs, stones, or in excavations. The eggs of some aquatic species, with their gelatinous envelopes, frequently resemble frog eggs, and they are laid in strings or clusters, according to species. The larvae are

born with external gills. Balancers are present in certain forms. In their development, the front legs appear first, while the tadpole larvae of frogs and toads develop hind limbs before the front ones

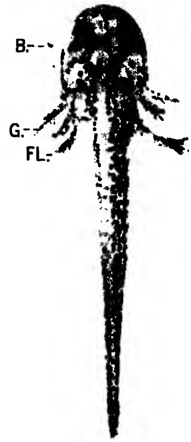


Fig. 163. The vermilion spotted newt (*Triturus viridescens*). Adult at left; Larva at right. B. Balancer; FL. Front legs; G. Gills. (Greatly enlarged.) Photograph of adult by P. L. Crummy; Larva, original.

appear. Some species, such as the water dog or mud puppy, retain their gills throughout their entire lives; but in most of them the external gills disappear shortly after hatching. In some sections the tiger salamander (*Ambystoma tigrinum*) never completes its metamorphosis but continues to grow to full size without losing its gills. The life histories of salamanders are quite variable, even within a single family. The period of metamorphosis from the egg to the adult stage ranges from a comparatively few weeks to several years. While the eggs of a few species are fertilized after

laying, as among most frogs and toads, in many of them internal fertilization is effected in an interesting fashion. The male deposits a pedestal-like capsule or spermatophore in which the spermatozoa are enclosed. The female gathers this into her cloaca, and the eggs are fertilized within the oviducts. In a few cases the female holds the eggs in the oviducts until the young are fully formed and reproduction is ovoviviparous.

The ecological and geographical distributions of species are interesting and in some cases unique. Such studies assist in determining relationships between individuals and groups. Local distribution shows that there is a distinct habitat selectivity evidenced by the various kinds of salamanders and newts. Some are found only in rapid brooks or in creeks, springs, ponds, or rivers. Others are terrestrial, and these usually inhabit damp woods where they lurk under logs and stones, while still others are most frequently found among loose, wet shales.

FIG. 164. The horned lizard or horned toad. Courtesy Denoyer Geppert Co.

There is also a general distribution of kinds according to latitude and longitude. Some species are termed southern, others western, and so on. One species may range from Virginia to Florida; another may be found from Maine, New York, and Pennsylvania westward to Michigan. Regardless of the extent of its distribution, every species is limited; and beyond the boundaries of its range is found another species, subspecies, or variety.

It would be difficult to make general statements about the habits of the salamanders inasmuch as there are alternate migrations from water to land or from land to water. It will be seen later that some larvae which hatch on land immediately take to the water, while some aquatic species assume a terrestrial existence shortly after they are born.

Nearly all of the newts and salamanders are nocturnal in their habits; and practically every one of them is carnivorous, feeding upon insects, worms, snails, slugs, and small fishes. Food is taken

in various ways, usually by stalking their inactive victims. Not all salamanders have tongues; and those that do, obtain their food in much the same manner as toads and frogs, frequently leaping after their victims.

Many of the salamanders have teeth, both maxillary and vomerine; and here again the transitional characters of these primitive amphibians are revealed. The teeth may be present in only one sex or they may be present in larva and lost before maturity is reached. The dental characters are so extremely variable and so difficult to interpret that their discussion would be out of place here. In the common two-lined salamander, *Eurycea bislineata*, the front maxillary teeth of the male are different from those of the female, being larger and directed forward. In the dusky salamander (*Desmognathus*) vomerine teeth are present in the female but absent in the male. While many Amphibia have teeth, none of them is known to use them for defense.

Fig. 165. The mottled salamander (*Ambystoma opacum*). Courtesy Gen. Biol. Supply Co.

It has been mentioned elsewhere that the skin of amphibians contains glands which secrete mucous material. Sometimes these secretions are poisonous, and they are effective in affording protection to those species in which poisonous glands are present. The poisons are only virulent, however, when they are injected or eaten; and seldom do they affect the bare flesh. A number of salamanders have odors which are offensive to us and which help to protect them from enemies. The primary functions of the odors are for courtship and for identifying others of their kind.

As a rule there is little difference in coloration between the sexes. Frequently, however, secondary sexual characters may be found. Courtship glands for attracting the opposite sex sometimes occur as swellings on the tail or as scattered glands on the eyelids. In some species these glands are on the chin or cheeks. Occasionally the male has its feet modified in the breeding season for holding the female during coition. Sometimes there are suction discs or nuptial spines developed for this purpose. These spines are located on the outer fingers of the front feet. The male may even have swollen glands or additional structures such as skin

flaps on the back during the mating season only. The newts and salamanders do not call their mates as do the frogs and toads, and the courtship glands serve in place of sounds. The habit of congregating in great numbers in certain locations during the mating season brings the sexes together. The scattered individuals, feeling the urge to reproduce, migrate to a stream; and the presence of a few in a desirable location is soon discovered by others. Sometimes the "marriage mart" has thousands of both sexes. Stream-inhabiting species may have their feet modified for holding on to the stones in the currents.

Fig. 166. The common toad (*Bufo americanus*) croaking. Courtesy A. A. and A. H. Wright.

Many common superstitions have developed about the salamanders, but none of our American species is formidable in any way. Newts do not jump down people's throats, and water dogs do not bite off the toes of swimming boys. For ages the belief has persisted that salamanders can endure fire; and safes, fire pots, and fire-proof insulation are frequently called "salamanders." While many salamanders can throw off milky secretions from their skin as a means of protection, they are, nevertheless, not impregnable; and they are devoured by many kinds of enemies.

The kinds of newts and salamanders. All of the North American newts belong to the family *Pleurodelidae* (*Salamandridae*). The commonest and most conspicuous species belong to the genus *Triturus* (Fig. 163). The common water newt or vermillion spotted newt, *Triturus viridescens*, is represented by two types. The small, orange, or brick-red newts found under stones or logs in damp woods are the land forms of a larger (4 inches) inhabitant of ponds or quiet stretches of water where they live among the aquatic plants. The water form is greenish above, while the entire ventral surface is a bright yellow with myriads of small black spots. Along the side is a row of scarlet spots, each of which is surrounded with a black border. Males may be distinguished from females by their swollen cloacas and more sturdy hind legs. The female

lays her eggs in capsules of jelly to protect them and attaches them to aquatic plants.

The larvae are born with external, branching gills extending horizontally from the neck just back of the head, and the front legs develop first. After eight or nine weeks the external gills disappear, and lungs develop. After a time, the young change from green to red, when they usually leave the water to spend a year or more on land, returning again to the water where they assume the adult coloration and where they spend the remainder of their lives.

There are four species of *Triturus* in North America, according to Noble, the western form being the largest and having the roughest skin. In the midwestern species, *T. meridionalis*, the red spots are not distinct but more or less united into a broken line. The southern species, *T. viridescens symmettrica*, more nearly resembles the midwestern species.

FIG. 167. Fowler's toad (*Bufo fowleri*). Courtesy A. H. Wright.

Most of the local salamanders belong to the family *Plethodontidae* with brook-inhabiting and terrestrial species. They are all lungless and may be distinguished from other salamanders by a groove extending from the nostril to the lip.

The most conspicuous eastern plethodontid is the coral-red salamander, *Pseudotriton ruber*, found under stones in brooks and occasionally in wet, swampy places. The young are a bright coral red with small, irregular black spots all over the back and sides. The adult is reddish with the black spots larger in size, and it has a purplish sheen. The young of this species is much larger (4 to 7 inches) than that of *Triturus*, and it breathes through its throat membrane and moist skin. The eggs, numbering more than 50, are attached singly to the undersides of stones in running water by a jelly-like stalk.

The purple salamander, *Gyrinophilus porphyriticus*, is an inhabitant of cold streams where the female deposits the eggs in clusters on the undersides of stones. The adult is a light pink mottled with darker spots.

The two-lined salamander, *Eurycea bislineata*, is found under stones and in the mud along the shores of small streams. The

adult is a small, slender, yellow or light brown salamander with a dark line on each side of the back extending from the eye backward along the tail. The sides are finely speckled with black. Each egg is attached to the underside of a stone in the current by a stalk of jelly. Metamorphosis is slow, sometimes requiring two years. Another native species is *Eurycea longicauda* which differs from *E. bislineata* in having a longer tail.

The dusky salamander, *Desmognathus fuscus*, is found in crevices and under stones in wet places. It has a stout body and measures almost six inches in total length. It is a dirty reddish brown on the back and dull gray underneath. The cream-colored eggs numbering 18 to 20 are deposited in grape-like clusters in moist cavities near a stream. The larvae are able to crawl about upon hatching. The female guards her eggs by wrapping herself about them. After hatching, the larvae develop in the water or remain on land for several weeks and then enter the water for a period of eight or ten months. Immediately after leaving the water they breed. All the species of *Desmognathus* have a diagonal light mark on each side of the head which extends backwards and downwards from the eye to the angle of the jaw, and all of them have rounded tails.

FIG. 168. The tree toad (*Hyla versicolor*). Photograph by F. Harper and A. H. Wright.

Another member of the family is the very small, four-toed salamander, *Hemidactylium scutatus*, which sheds its tail quite readily when captured. It is brown above, shiny white or slightly yellowish underneath, with tiny black dots; and it has a yellowish snout. The species is terrestrial and can be readily identified by the constriction at the base of the tail and by having only four toes on the hind limbs. The eggs are deposited near ponds in wooded sections.

The genus *Plethodon* includes a number of terrestrial species which are quite common in eastern United States. The red-backed salamander, *P. cinereus*, is more frequently found in coniferous

woods under logs and stones in damp places. Its dozen or more white eggs are usually deposited in hollow logs. The slimy salamander, *P. glutinosus*, is almost black with whitish flecks on the back and sides. It is much larger than the red-backed salamander. The white eggs are laid in caves or under stones. In both of these species the external gills are lost immediately after hatching.

The family *Ambystomidae* includes the largest and most common species of terrestrial salamanders. Most of them lay their eggs in the water, and the larvae have broad bodies and tail fins. The gills are large and conspicuous. The spotted salamander, *Ambystoma maculatum*, is found under logs and stones in damp places. The adult, which measures up to nine inches, is a shiny black with a number of large, yellowish, rounded spots on each side of the body and tail. The underside is a dull gray with flecks of bluish white. Its clusters of large eggs are deposited in ponds early in the spring. Sometimes thousands of adults congregate in ponds or slow streams at night during the breeding season. The males deposit spermatophores about one-half inch long containing hundreds of spermatozoa. The females crawl over these and take the spermatozoa into their cloacas.

The tiger salamander, *A. tigrinum*, is a sturdy species about eight inches long. Its markings vary tremendously in different parts of its range. It may be a dull black with yellow blotches running together so as to form cross bars resembling stripes. The underside may be mottled black and yellow, excepting the chin which is yellow. The tiger salamander is found under logs and stones near cold streams or spring-fed ponds. In some western and southern regions the external gills are retained in the adult stage, and the individuals remain in the water. In other words, the larval characters persist throughout life. These gilled forms are called axolotls (Plate XIV, Fig. E).

The marbled or mottled salamander, *A. opacum* (Fig. 165), is the only species in the family *Ambystomidae* which may lay its eggs on land where they are deposited under logs or stones. The eggs are usually deposited near a stream in a place that will later be flooded. The larvae go into the water as soon as they are born. The adult is a dark gray with irregular whitish bars on the back. It is sometimes confused with the tiger salamander, but it may be distinguished by its absence of yellow.

Jefferson's salamander, *A. jeffersonianum*, is another common

species in eastern sections. It is an olive-brown or blackish species with pale bluish spots on the back, although it may be uniformly brown with flecks of pale blue on the underside. The adult measures about six inches or more.

The mud puppy or water dog, *Necturus maculosus*, is the second largest of the common salamanders (Plate XIV, Fig. C). It belongs to the family *Proteidae* (*Necturidae* of some authors) and attains a total length of 12 inches or more. Its large head is broad and flat. The water dog is called a larval salamander because it retains its very large, conspicuous, reddish gills throughout its life which is spent in the water of lakes, rivers, large ponds, or creeks.

Its mottled brown color resembles the bottom and affords protection. The mud puppy feeds on worms, insects, and fishes, and is frequently taken on baited hooks. The large eggs are attached singly to the objects in the water, and the larvae have short limbs.

Fig. 169. The spring peeper (*Hyla crucifer*). Courtesy A. A. and A. H. Wright.

The family *Cryptobranchidae* includes the giant salamander of Japan. This salamander attains a length of five feet. The family has a single representative in America (Plate XIV, Fig. B). It is the hellbender, *Cryptobranchus alleganiensis*, which measures up to 24 inches and is found sparsely distributed in eastern United States as an inhabitant of the waters of rivers and lakes. It has an olive-green color with darker splotches irregularly distributed on the back, but it may be dull red-brown in some streams. Its eyes are extremely small, and there are no external gills. The thick skin is loose and gathered into folds along the sides. While the hellbender has lungs, it apparently does not use them to a great extent; and respiration is effected largely through the slimy skin.

The female lays her strings of eggs in excavations made by the male; and after the male has fertilized them, he guards the nest

until the young are born. The hellbender is a serious menace to the fish population. It also eats a large number of crayfishes.

The frogs and toads. The order *Salienta,* which includes the frogs and toads, differs from the *Caudata* in that its members are tailless; and they have short, stout bodies and sturdy legs. The legs have four segments while those of salamanders have but three. Only one species, *Ascaphus truei,* of American frogs has a caudal appendage; and this is an extension of the cloaca which greatly resembles a tail. In this form alone, fertilization is internal, the extended cloaca serving as a copulatory organ. It is found only in the Northwest. The order is represented in the United States by the six following families:

Fig. 170. The green frog (*Rana clamitans*). Courtesy A. A. and A. H. Wright.

(1) *Liopelmidae,* primitive frogs with a single genus (*Ascaphus*) in the Northwest.

(2) *Pelobatidae,* the burrowing toads, including the eastern spadefoot toad.

(3) *Bufonidae,* the true toads, including the common garden varieties.

(4) *Hylidae,* the tree frogs, including the spring peeper, etc.

(5) *Ranidae,* the true frogs, including the green frog, pickerel frog, and bullfrog.

(6) *Brevicipitidae,* the narrow-mouthed toads.

The group is frequently referred to as *Anura,* and it includes the most interesting and musical of the amphibians. The frogs and toads are familiar animals to most persons. Sounds are produced by means of vocal sacs. These are located in the skin on the sides of the neck. Air is forced into the mouth and vocal sac from the lungs through the glottis and back again. The males are much more capable of producing sounds than are the females. In croaking the mouth is kept closed. (See Sound.) The toads are chiefly terrestrial creatures with dry, warty skin; and many of them lack the fully webbed feet which characterize their close aquatic relatives, the frogs. Both usually lay their eggs in water, and they undergo a similar metamorphosis. The eggs of frogs are laid in clusters, while those of the toads are deposited in

strings. When the group is considered as a whole, however, it is difficult to generalize about their life histories because there are many modifications of breeding habits, metamorphoses, and life histories. Some of these variations will be referred to later. In most cases the sexes are similar, but the male usually has a swollen thumb which enlarges greatly during the breeding season. The external features of a frog are shown in Fig. 162.

The common garden toad is worthy of observation. It is a rather formidable-looking creature; yet it cannot bite, sting, or run away from many enemies. Its chief defenses lie in its ability to conceal itself in shallow depressions in the loose dirt. In these, its warty, ground-colored skin resembles the background so well that the animal usually escapes observation. When attacked, it emits a distasteful, poisonous, and ill-smelling fluid which frequently protects it from being devoured. An inexperienced dog or cat which grabs a toad for the first time soon lets go of it and endeavors in many ways to eject the fluid from its mouth. The toad is usually nocturnal, but sometimes it forages during the daylight hours. On one occasion, the writer observed a toad moving along a row of cabbages during the day, leaping from the ground to pluck the worms from the leaves. As a rule, however, the toad is a more or less sedentary hunter. Remaining motionless in one place, it waits patiently for passing insects to come within reach. Sometimes it leaps for flying insects; and occasionally it waits with its doubled, sticky tongue extended until its victims alight on it. The tongue is attached to the front of the mouth and is split at the end. As a rule, the toad does not migrate far from its birthplace. An aluminum band was placed on the leg of a garden toad, and it was observed in the same place on five consecutive seasons. At the farm where the observations took place, there was a pipe connected with a natural gas well. A perforated tin can was placed over the exposed end of the pipe, and the es-

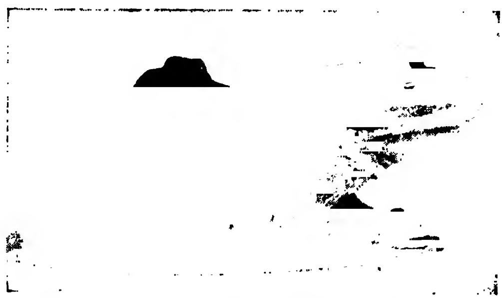


FIG. 171. The bull frog (*Rana catesbiana*). Courtesy A. A. and A. H. Wright.

caping gas was lighted. On warm summer evenings the light attracted myriads of insects which singed themselves by flying into the flame. Each night the toad came from its hiding place and stationed itself on the ground under the light and gulped down the insects as they fell to earth.

In winter the toad, like all other amphibians, hibernates in a place protected from the freezing temperatures. Its vital processes are reduced to a minimum, and it is nourished by the excess of tissues built up during the summer months. In the spring it ventures forth to seek a mate. The male migrates to a pond or stream and soon begins calling or croaking. The females respond to the male calls as they follow the males to the water, but their calls are not so deep or loud as those of the males. Mating usually takes place in the water. The return to the water is probably a response to the call to her original home; and her eggs are deposited in long strings in the shallow water, usually while the male clings to her. Fertilization is effected by the male who discharges spermatozoa upon them. The eggs are covered with a substance that absorbs considerable water; and within a few hours after they are laid, they become enveloped with a thick, clear, jelly-like encasement. This covering protects the eggs from injury, from sudden changes of temperature, and from destructive evaporation. It also acts as a convexo-concave lens which serves to gather and focus warm light rays on the developing egg and thus assists in incubating it.

FIG. 172. The leopard frog (*Rana pipiens*). Courtesy A. H. Wright.

Upon examination, the eggs are seen to be spherical, with one-half black and the other half cream-colored or whitish. The black portion is the animal pole in which the larva or tadpole develops. The other half is the vegetative pole and contains the yolk which nourishes the developing embryo. The black half is usually turned upward and exposed to the light. Being black it absorbs the light, and development is accelerated. When the larva is sufficiently developed, it wriggles out of the gelatinous mass into the surrounding water. The tadpole, as the larva is called, has small external gills extending outward from the neck. The young immediately attaches itself to some submerged object with its adhesive disc

and remains stationary for a few days. Soon the external gills disappear, and the tadpole feeds on the slimy algae which covers the stones in still water. As the animal grows, it becomes more active and swims about with an undulating movement, propelled by the broad, fin-like tail. After several weeks the hind legs appear; and some time later the front legs, which have been developing within the opercula, are extended. The tail is gradually absorbed or "resorbed" and not lost as some people suppose. In the meantime lungs are developing; and when the tail has completely disappeared, the young toad leaves the water and takes up a terrestrial existence. It returns to the water only during the breeding season or in periods of severe drouth.

FIG. 173. The cricket frog (*Acris gryllus crepitans*). Courtesy A. A. and A. H. Wright.

Toads are valuable and harmless animals, rendering a service that is immeasurable by their destruction of harmful insects. While they do emit milky fluids when disturbed, the secretion does not cause warts as is too commonly supposed. The belief that the killing of a toad will bring rain is just another superstitious fallacy.

There are about 18 species and subspecies of toads in the United States, but the following are the two principal representatives of the *Bufonidae* in the eastern United States. Both of them are toothless and have the toes webbed at least half their length.

The American toad, common toad, or garden toad, *Bufo americanus* (Fig. 166), ranges from Hudson Bay to the southern states. The color is brownish, reddish brown, and rarely grayish, or greenish. The underside is rough, light-colored, and generally black spotted. The upper surface of the head, back, and hind legs is very rough with irregular, horny warts. Its roughness increases with age.

Bufo fowleri, Fowler's toad, or the little toad, is a slightly smaller and more active species than the common toad (Fig. 167). It is less rough with smaller and less conspicuous warts. The skin is soft, dull, or light gray in color, sometimes with a greenish tinge

which is not characteristic of the common toad; but it may be brick-red at times. There are dark spots on the back, and each spot usually encircles several small warts. The underside is also sometimes dully spotted.

The species has a wide range, extending from Massachusetts to Georgia and westward to Michigan and Missouri and along the Gulf of Mexico to Texas. Its habits are somewhat similar to those of the larger common toad. Both of these toads have a harsh trill which is heard during the breeding season. Fowler's toad has a less prolonged song.

The eastern spade-foot or burrowing toad, *Scaphiopus holbrooki*, is a representative of the family *Pelobatidae*. It has teeth in the upper jaw, and there is a distinct spade-like spur or plate on the heel for digging. The toes are only slightly webbed. The general color is an olive-brown with a yellowish band on each side. The skin is almost smooth or only slightly tubercled. The forehead is rather rough and bony. The pupil of the eye is vertical instead of horizontal as in the ordinary toad.

Fig. 174. The wood frog (*Rana sylvatica*). Courtesy A. A. and A. H. Wright.

The tree frogs, *Hylidae*, may be identified by examining their fingers and toes which are dilated at their tips into viscid discs which enable them to cling to the bark on trees. They comprise a group of very noisy species, many of which can change their color to that of the background on which they rest.

Perhaps the commonest member of the family is the spring peeper or Pickering's toad, *Hyla crucifer* (Fig. 169), whose shrill whistle is the real harbinger of spring. When winter breaks and the warm, balmy, humid weather of spring comes, the night air is pierced with the songs of thousands of spring peepers. The sound is produced in their greatly dilated vocal sacs which are swollen-like blisters while they sing. The spring peeper is a small, yellowish, or cream-colored species with radiating lines on the back arranged so as to form an "X" or oblique cross. There are cross bars on the upper surfaces of the hind limbs and one across the top of the head, connecting the eyes. The discs on the fingers

and toes are rounded. Like all of the local tree frogs, the spring peeper breeds in the water; and after development is completed, the young frogs sometimes, although rarely, ascend the trees or other coarse vegetation where they remain until fall, descending upon the approach of cold weather to hibernate in the ground. All of the tree frogs feed upon insects.

The cricket frog, *Acris gryllus*, rarely ascends into the trees but remains among the low vegetation at the edge of a pond. It also inhabits the swamps of eastern United States. It is less than an inch and a half long and has very long hind legs. The color is generally brownish above with the middle of the back sometimes a bright green. There is a dark triangle between the eyes, and there are three oblique blotches on the sides. A whitish line extends from each eye to the arm. Its call resembles that of a cricket and is somewhat different from the calls of other tree frogs. In fact, all of the species can be identified by their calls. Like all of the other tree frogs, too, the cricket frog is much more frequently heard than seen. Its toes are strongly webbed, and it is an excellent swimmer.

The swamp tree frog, *Pseudacris nigrita triseriata*, is also very small, measuring less than an inch and one-half in length. It also lives near the ground and seldom ascends trees. It differs from the other swamp tree frog, *Pseudacris nigrita feriarum*, by having a more pointed snout. In the latter there is a dorsal line extending from the snout backward and bifurcating about the middle of the body and a line on each side of this and one on each side of the head; in the former there are three dorsal stripes extending backward, the middle one often dividing or forking behind. Both are ashy gray in color.

The common tree frog or rain toad, *Hyla versicolor* (Fig. 168), is about two inches long and is gray, brown, or green in color, with irregular dark blotches. Its underside is white or cream-colored; and the groin, axilla, and under portions of the hind limbs are orange. By contracting and expanding the black pigment cells in the skin, it can change its color to blend with the background. When the cells are expanded, the color becomes much darker. There also are yellow pigment cells in the skin; and when the black cells are contracted, the body appears to be a light greenish yellow. The fingers are slightly webbed, and the skin is slightly warty. There is a whitish spot under each

eye. The rain toad is a rather vociferous creature, especially in wet weather.

Anderson's tree frog, *Hyla andersoni*, is another less common species in eastern United States. It is a deep pea green with asymmetrical yellow spots on the sides. There is also a green spot on the throat. It measures about one and one-half inches, and its habits are somewhat similar to those of the spring peeper.

The true frogs (*Ranidae*) are much larger than the tree frogs, and all of them have well-developed teeth in the upper jaw. Their toes are well webbed, and all of them are good swimmers. All of the frogs breed in the water, and all of them remain in the vicinity of it after completing their development. There are numerous species of frogs, and only the more common ones are presented here.

The common green frog, *Rana clamitans* (Fig. 170), is found generally distributed throughout eastern United States. The color is usually bright green above anteriorly and occasionally brownish with dark, irregular spots. The underside is yellowish or white, and the arms and legs are blotched above. The toes are well webbed, and the glandular folds of the skin are large. Length is about four inches.

The pickerel frog or brown frog, *Rana palustris*, is rather common in the higher regions of the East. It is light brown above with four rows of dark brown, asymmetrical blotches. There is a brown spot above each eye. A dark line extends from each nostril to the eye. The underside is white, and the concealed surfaces of the hind legs are yellowish or orange. It measures about three inches in length.

The leopard frog, or grass frog, *Rana pipiens* (Fig. 172), is an abundant species in the marshes and ponds of the entire eastern section of the United States. Its range extends westward to the Sierra Nevada Mountains. It is commonly used in laboratory studies. Its upper surface is a brownish green to bronze with light-edged, irregular black blotches arranged in two or more rows along the back. The legs are barred above, and the head is more elongate than in the preceding species. There are two spots between the eyes. The underside is a pale cream color.

The bullfrog, *Rana catesbiana* (Fig. 171), is the largest of native frogs, having a total length of eight inches in full-grown animals; with the hind legs extended it reaches 12 to 14 inches. The head

is usually a bright green; but the rest of the dorsal surface is somewhat darker with faint, inconspicuous darker spots. The underside is whitish, but the throat is frequently yellowish. The tympana are much larger on males than on females. While it is a native of the eastern and midwestern sections, the giant variety has been distributed throughout the entire country and in fact throughout the world. It is raised extensively for food.

The wood frog, *Rana sylvatica* (Fig. 174), is a beautiful species of frog with terrestrial habits. It is usually found in low, damp woods where it actively forages night and day. It is much smaller than most of the others, measuring about three inches. The color varies from greenish to reddish brown, and a dark band extends along each side of the head over the eye and ear to the insertion of the arms. The sides are speckled with black. The head is small and pointed, and the legs and arms are barred with black on their upper surfaces. The underside is whitish.

The narrow mouth toads (*Brevicipitidae*) are mostly tropical, but at least four species occur in the South from Virginia to Texas. In some of the tropical species, the eggs hatch directly into frogs and the young do not pass through the various stages of metamorphosis.

BIBLIOGRAPHY

Amphibia

Adams, L. A., *Necturus—A Laboratory Study*. Macmillan, 1926.

Bishop, S. C., *Notes on the Habits and Development of the Mud-puppy, Necturus*. N. Y. State Mus. Bull. No. 268, 1926.

——, *Notes on the Habits and Development of the Four-toed Salamander, Hemidactylium scutatum* (Schlegal). N. Y. State Mus. Bulls. 219, 220, 251, 282 (1919).

——, *The Amphibians and Reptiles of Alleghany State Park*. N. Y. State Museum, Albany Handbook, III, 1927, pp. 1–141.

Blanchard, F. N., "The Life History of the Four-toed Salamander," *American Naturalist*, LVII, 1923, pp. 262–268.

Boulenger, G. A., "On the American Spade Foot (Scaphiopus solitarius Holbrook)," *Proc. Zoöl. Soc.*, London, 1899, pp. 790–793, 1 pl.

Butler, A. W., "Hibernation of the Lower Vertebrates," *Amer. Nat.*, XIX, 1885, pp. 37–40.

Cope, E. D., *The Batrachia of North America*. Bull. U. S. Nat. Mus., No. 34, 1889.

Dickerson, Mary C., *The Frog Book; North American Frogs and Toads,*

with a Study of the Habits and Life Histories of Those of the Northeastern States. Doubleday Page, 1906.

Dunn, Emmett Reid, *A Preliminary List of the Reptiles and Amphibians of Virginia.* Copeia, No. 53, 1918.

——, *Reptiles and Amphibians Collected from the North Carolina Mountains, with Special Reference to Salamanders.* Bull. Am. Mus. Nat. Hist., Vol. 37, 1917, p. 593.

——, *The Salamanders of the Family Plethodontidae.* Smith College Pub., Northampton, Mass., 1926.

——, *The Salamanders of the Genera Desmognathus and Leurognathus.* Proc. U. S. Nat. Mus., Vol. 53, 1918, p. 393.

Fowler, Henry W., *The Amphibians and Reptiles of New Jersey.* Ann. Rep. N. J. State Mus., 1906.

Gadow, Hans, *Amphibia and Reptiles.* Cambridge Nat. Hist. VIII (London), Macmillan, 1901.

Goldsmith, G. W., *Habits and Reactions of Scaphiopus hamondi.* Yr. Bk. Carnegie Inst. Wash., 1924 to 1925, XXIV, pp. 340–341.

Hargitt, C. W., "Behavior and Color Changes of Tree Frogs," *Jour. Anim. Behav.*, II, 1912, pp. 51–78.

Hay, Oliver Perry, *Batrachians and Reptiles of Indiana.* 17th Rep. Geol. Sur., 1892, p. 412.

Hegner, R. W., *College Zoölogy.* Macmillan, 1932.

——, *The Parade of the Animal Kingdom.* Macmillan, 1935.

Hodge, C. F., *The Common Toad.* Nature Study Leaflet, O. B. Wood, Worcester, Mass., 1898.

Holmes, S. J., *The Biology of the Frog.* Macmillan, 1927.

Hurter, Julius, Sr., *Herpetology of Missouri.* Trans. Missouri Acad. Science, Vol. 20, St. Louis, Mo., 1911.

Jordan, David Starr, *Manual of the Vertebrate Animals of the Northeastern United States.* World Book Co., 1929.

Kellogg, Remington, *The Toad.* U. S. Dept. Agr. Bur. Biol. Survey, M. S., 1922.

Lancaster, E. R., *A Treatise on Zoölogy.* Macmillan, 1909.

McAtee, W. L., *Homing and Other Habits of the Bullfrog.* Copeia, No. 96, 1921, pp. 39–40.

Morgan, Ann, *Field Book of Ponds and Streams.* Putnam, 1930.

Netting, M. Graham, *The Amphibians of Pennsylvania.* Proc. Pa. Acad. Sci., VII, 1933, pp. 100–110.

——, *A Non-technical Key to the Amphibians and Reptiles of Western Pennsylvania.* Na-Wak-Wa Fireside, N. S., Nos. 3 and 4, 1935, pp. 34–49.

Noble, G. K., *Biology of the Amphibia.* McGraw-Hill, 1931.

Noble, G. L., and R. C., "The Anderson Tree Frog (Hyla andersoni

gether with the legs, may be withdrawn between the two shields in some species. The upper shield is called the *carapace,* and the ventral one is called the *plastron.* The turtles have no teeth, but the jaws are encased in horny sheaths which usually have sharp, cutting edges. The eye has two lids and a nictitating membrane like that on the eyes of birds. Respiration is usually effected by swallowing air, although pharyngeal respiration is known in some species.

Turtles are both terrestrial and aquatic. In the truly aquatic kinds such as the marine turtles, the legs are modified into flippers for swimming, while the pond- and stream-inhabiting kinds have webbed feet. The large sea turtles such as the trunk turtle and the green turtle may attain a weight of upwards of 1000 pounds and a length of more than six feet.

Many of the marine and fresh-water turtles are edible and they are much sought after as food both in the tropics and in the temperate zones. The giant green turtle is considered the finest of the marine species. The green turtles are chiefly inhabitants of the warm subtropical and tropical seas, although they are frequently taken off the coast of the New England states.

Turtles are mostly carnivorous, feeding upon fish, birds, mollusks, and other animals, although many of them include water plants in their diet. All of the turtles lay eggs—on land. Even the giant sea forms seek the sandy beaches at night and deposit their eggs in the sand, above the high-tide line. The female scoops an excavation in which she places her eggs and then covers them. Most of the pond and stream forms place their eggs in sandy excavations, frequently at a considerable distance from the water. When the young hatch, they immediately migrate to the water. Turtle eggs vary somewhat in shape; and all of them have a whitish, leathery, or hard-shell covering. The eggs of many species are excellent articles of diet. There are four principal families of turtles in the eastern United States, exclusive of the marine species. Some of the commoner species of turtles representing the various family groups are as follows:

The box turtles (family *Testudinidae*) are so named because the plastron is divided by a central hinge which permits the front and back parts to be drawn against the lower edge of the carapace to which the plastron is attached by an elastic, cartilaginous joint. In this way these turtles can withdraw completely into the shell.

Some of the box turtles live in ponds and swamps where they bask on protruding logs and from which they tumble quickly into the water at the least disturbance. These usually have only partly webbed toes. The shells of the pond dwellers are elongate and globular, and they are usually smooth. In some of them the anterior half of the plastron is more movable than the posterior half, and these are called semi-box turtles. Several common species of the semi-box turtles are generally distributed in the East. Blanding's turtle (*Emys blandingii*) is almost eight inches long and five inches wide. Its upper shell is black with numerous pale yellow or whitish spots. The plastron is yellow in the center with large, dark blotches around the pale area. The head is black above with many yellow spots, and the chin and throat are bright yellow.

FIG. 187. The painted turtle (*Chrysemys picta marginata*). Courtesy N. Y. Zoöl. Soc.

Another common species is the common box turtle (*Terrapene carolina*) which ranges all over the eastern and central states (Fig. 190). It has a highly arched and globular carapace which is dark brown above with numerous yellow spots or splotches, although the color pattern is extremely variable. The plastron may be almost black, or black covered with large yellow spots. The males of this species have red eyes and the females have yellow eyes. The species is about five and one-half inches long and two and one-half inches high. It is largely terrestrial and wanders about without making permanent excavations. Its food consists of berries, fungi, worms, snails, and insect larvae. The eggs of the box turtle are buried in the ground or covered with leaves. It hibernates deep in the ground and it is supposed to live for very many years.

The painted turtle (*Chrysemys picta marginata*—family *Testudinidae*) is one of the commonest eastern aquatic species; it has a smooth, flattened carapace (Fig. 187). The plates of the shell are

olive brown with borders of pale yellow, and the small marginal plates are red with black and yellow markings which are plainly conspicuous on the underside. The plastron is a bright yellow. There are two bright yellow lines behind each eye and yellowish streaks which seem to disappear in scarlet on the throat, legs, and tail. The variety of color gives the species its name. The size is not over eight inches, measured from the anterior to the posterior ends of the carapace.

The painted turtle is an inhabitant of plant-filled ponds where it feeds upon plants, insects, and mollusks. Its nest consists of a hole (dug by the female) in the ground not far from the water. The leathery eggs, from four to eight in number, are pinkish in color.

Fig. 188. The musk turtle (*Kinosternum subrubrum*). Courtesy N. Y. Zoöl. Soc.

The species and its varieties are generally distributed over the eastern United States and southward to Georgia and Alabama.

The spotted turtle (*Clemmys guttata*) is found in the same situations as the painted turtle (Fig. 189). It has a smooth black flat carapace which is covered with irregularly arranged orange or yellow dots. The undersides of the carapace are marked with yellow, and the middle of the plastron is dull yellow. The tail of the male is almost twice as long as that of the female.

The wood turtle or sculptured turtle (*Clemmys insculpta*—family *Testudinidae*) is a small turtle (8 inches) which inhabits woodlands and is occasionally found in open fields (Fig. 191). It may be identified by the roughly sculptured concentric rings on each plate of the carapace. The carapace is a mixture of gray and brown. The head and feet are rusty brown, and the other soft parts are a dull salmon color. The wood turtle feeds upon berries, fungi, and mollusks when on land. In the water, where it mates and hibernates, it feeds upon almost anything that lives in an aquatic situation. The whitish eggs are laid in excavations in the ground.

The three-toed box turtle (*Terrapene triungus*) is similar to

T. carolina, but the hind feet are narrower and they are equipped with only three claws. It is found from South Carolina to Florida and westward.

The soft-shelled turtle (*Amyda spinifera*—family *Trionychidae*) is a flat-bodied turtle with a narrow head and prolonged snout (Fig. 193). The nostrils are located at the tip of the snout, where they can protrude above the surface of the water while the animal floats just below the water level. The carapace is soft and leathery and lacks the bony plates which characterize other turtles. Its color is a yellowish brown covered with scattered small black dots. The plastron is almost white. The species is aquatic and leaves the water only to lay its eggs which are deposited in excavations near the shore. The maximum length of the carapace is approximately 14 inches. It is sometimes called the leather-back turtle. It is a vicious species, and caution should be exercised in handling it.

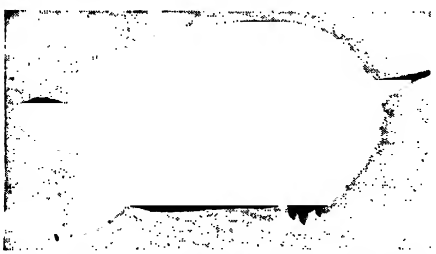


FIG. 189. The spotted turtle (*Clemmys guttata*). Courtesy N. Y. Zoöl. Soc.

The musk turtles or mud turtles (*Kinosternidae*) include a number of species of small turtles generally distributed throughout the eastern United States (Fig. 188). The shape and other characters of the shell are variable according to where the species are found. The common musk turtle (*Sternotherus odoratus*) has a keeled carapace when young; but the keel disappears with age, and the nearly oval carapace retains only a fairly high arch in the adult. The color is a dull olive brown, although in old specimens the color is usually obscured by a covering of algae. The plastron is very narrow and colored a yellowish brown. The head has two bright yellow stripes extending from the snout to the neck, one of them passing over the eye. The species is only about four inches long; and it stays in the water in creeks and rivers, crawling about over the bottom feeding on fishes and other aquatic animals. It comes ashore only to lay its eggs. When captured, it emits a disagreeable odor; hence its name. It is slightly pugnacious and exhibits fighting habits similar to those of the snapping turtle.

The common mud turtle (*Kinosternum subrubrum*) is a widely distributed representative of a fairly large group. Its upper shell

is broader and more nearly flat than that of the musk turtle. The plastron is also wider. The color is similar to that of the musk turtle although the head is covered with numerous greenish-yellow spots. Sometimes these spots run together to form lines on the sides, resembling the musk turtle. The broad plastron, however, makes the distinction easy.

The snapping turtle (*Chelydra serpentina*—family *Chelydridae*) is the largest of the fresh-water turtles, attaining a length of almost three feet and weighing upwards of 45 pounds. The species is used extensively as food. It lives in the larger streams and ponds where it feeds upon water birds, frogs, and fish. It is quite an enemy of wild and domestic ducks. The carapace is rather small and allows the free use of the legs. As a result, the snapper is a fast walker on land, where it can frequently be found, often at a considerable distance from the water. The neck is long, and the head is so large that it cannot be completely withdrawn into the shell. The plastron is narrow, and it tapers from the middle toward both ends. The snapper is a vicious and formidable turtle with a horny beak that is capable of inflicting serious injury. It is a bad-tempered species, and it must be captured and handled with caution. It is found from the Rocky Mountains eastward (Fig. 192). Like most other water-inhabiting turtles, the snapper deposits its 20 or more round hard-shelled eggs in excavations on the shore. The eggs are about an inch and a quarter in diameter and they are edible.

FIG. 190. The common box turtle (*Terrapene carolina*). Courtesy N. Y. Zoöl. Soc.

3. **The lizards.** The lizards are long, slender, four-footed reptiles with long tails. It has already been suggested that the smooth-skinned, slow-moving, lizard-like animals found in watering troughs and in wet places are relatives of the frogs and toads and therefore belong to the Amphibia. The bodies of lizards are covered with scales, and their movements are quick. They inhabit dry sections where they feed upon insects which they capture.

While lizards are characteristic animals in tropical and sub-

tropical countries, there are many species in the United States, especially in the arid regions of the Southwest. However, there are several species of lizards in the eastern states; and they are found from New England to Florida. They usually escape observation by most people because of their shy dispositions. At the slightest disturbance they scamper away with lightning rapidity, or they remain perfectly motionless and are unseen because of their size and coloration.

The lizards have sharp teeth with which they crush the bodies of insects, frequently chewing their victims; and they have long, whip-like tails. The large tropical iguanas use their tails in defense, and they lash their attackers violently. In most species of lizards the tail is brittle at its point of attachment to the body, and it can be shed automatically. This is a characteristic defense mechanism among lizards in general. When disturbed, the lizard attempts to escape. It is usually swift enough to outdistance most pursuers, and all lizards can climb in an attempt to get away from enemies. However, they are often caught by other animals, usually by the long tail which is frequently almost the length of the body. The tail immediately drops off at its point of attachment to the body. In many lizards, and especially in the geckos, the tail writhes as though it were alive; and while the captor is interested in the antics of the tail, the lizard scampers away to safety. It then grows a new tail (sometimes two or three) in place of the one that was lost. This practice of shedding the tail (autotomy) is confusing to the captor; and the writer, while collecting lizards in the South American jungles, was fooled many times. When a lizard was grabbed quickly from the bark of a tree with the hands, it frequently happened that all the captor had was a writhing tail. Most lizards also bite in defense when they are captured.


FIG. 191. The wood turtle (*Clemmys insculpta*). Courtesy N. Y. Zoöl. Soc.

The tropical iguanas are sometimes more than four feet long; and in addition to using their tails to lash their captors, they defend themselves by biting and by scratching with their claws.

The iguanas also shed their tails when no other escape seems possible to them. The iguana is a delectable food, and it is much prized by natives and explorers. A female iguana may carry from 39 to 41 (author's field notes) oval, soft-shelled, white eggs. The eggs are about two inches long and almost an inch in diameter. They are excellent food.

The iguana is a grotesque-looking lizard with antediluvian characters, which include spines on the throat, head, and back. It has several representatives in the United States, and these are mostly confined to the Southwest with species in southern California and Arizona. In the tropics, the iguanas live along streams, resting upon the branches of trees that overhang the water. When disturbed, they drop into the water with a loud splash; and they remain submerged for some time, usually swimming under water and emerging a considerable distance away. In the United States we have a desert species which is found in Arizona. All of the iguanas belong to the family *Iguanidae.*

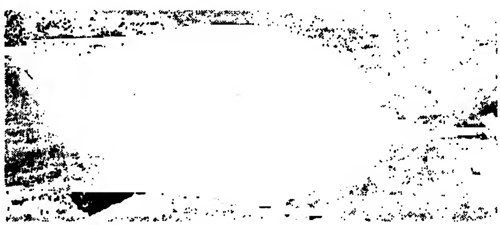


FIG. 192. The snapping turtle (*Chelydra serpentina*). Courtesy N. Y. Zoöl. Soc.

The American chameleon (*Anolis carolinensis*) is one of the most interesting and docile of native lizards. It is also a member of the iguana family and is in no way related to the true chameleons of the Old World. It is found from North Carolina southward to Florida and westward to Texas. Its remarkable ability to change its color, combined with its extremely docile nature, has caused it to become the best-known lizard in America with the possible exception of the gila monster. The chameleon is sold extensively at county fairs and at circuses. It can be kept alive in the home for an indefinite period provided it is supplied with plenty of water and food. It runs about over the curtains, house, and plants; and it catches flies and other insects. It will also eat roaches and meal worms.

The chameleon is usually a dull brown above; but when frightened it quickly changes to a bright green. According to Dr. Ditmars, the color changes are not made in response to back-

ground but rather are due to the mood of the animal. When frightened, fighting, or courting, the color is usually bright green. The males have a peculiar throat pouch which is extended as a flattened flap during courtship or when fighting another male. The battles between the males are vicious, and the victor usually struts about with the writhing tail of the vanquished in his mouth and with his bright green color more pronounced than ever.

The chameleon is usually found on plants or along fences and it is difficult to see because of its protective coloration. It is not so swift in its movements as most common lizards.

The geckos, or pad-footed lizards, have stout bodies and rather thick tails. The bodies are covered with very minute scales, and

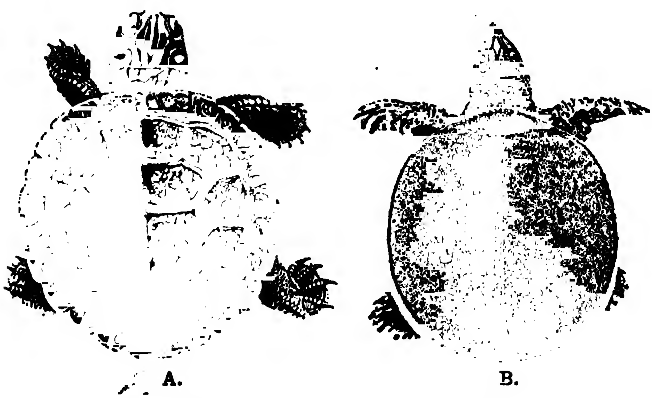


FIG. 193. Common turtles. A. Map or geographical turtle (*Graptemys geographica*); B. Soft-shell or leather-back turtle (*Amyda spinifer*). After Agassiz.

their scalation is not at all conspicuous. The skin has a warty appearance similar to that of a toad. The head is flat and pointed with swellings at the temples, and the eyes are large and prominent. The pupil of the eye is elliptical. The toes are flat and expanded into wide discs which enable them to walk upside down. There are several species of geckos in this country, and they are found in southern California and in southern Florida. They are abundant in the tropics, and many of them are brought into the United States with bananas. In the Guianas some of the geckos issue rather loud calls when they discover a stranger in their haunts. The call somewhat resembles the cackle of a hen. The geckos all belong to the family *Gekkonidae*.

The swifts are small, slender lizards with variable scales. They are inhabitants of drier regions; most of them are western, although there is one fairly common and universal species in the eastern states. The common swift (*Sceloporus undulatus*) is almost six inches long. Its scales are of medium size and coarsely keeled. The head scales appear to be wrinkled. The color is gray, brownish, or greenish, with narrow wavy cross bands on the back. The male has an irregular bluish-black spot on the chin and two bluish patches on the abdomen. The swift is found in dry, sandy regions, mostly in the South, from southeastern Pennsylvania and New Jersey to Florida and westward. The swifts also belong to the family *Iguanidae*.

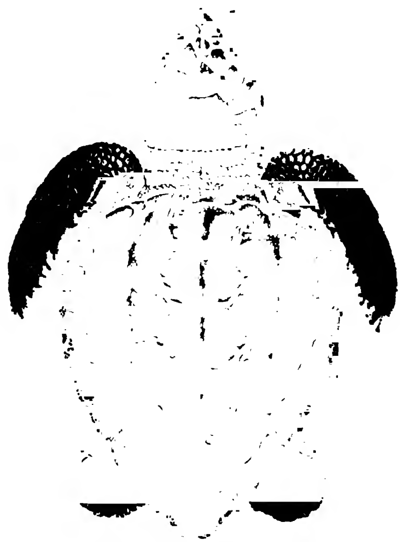


FIG. 194. A marine or sea turtle showing front legs modified for swimming. After Agassiz.

The family *Teiidae*, which includes the race runners or striped lizards, has one eastern representative, the six-lined lizard (*Cnemidophorus sex-lineatus*) which can be readily recognized by the six yellow stripes running from the head to the base of the tail. The body color is brownish with a broad brown band down the middle of the back. It is found from southern New Jersey and southeastern Pennsylvania southward.

The most common lizards in the eastern states are the skinks or smooth-scaled lizards. In the skinks the scales are small, smooth, and shining. The young animals are distinctly striped, but in older specimens the color is usually a dull brown with feeble stripes. Three species are found in eastern and central United States. The commonest eastern species is the black skink (*Eumeces anthracinus*), which is more commonly found in the regions of the Allegheny Mountains. It is commonly seen on hot days, running about over stones. The species is a dull olivaceous brown with two distinct white lines on the sides. The blue-tailed skink, five-lined skink, or red-headed lizard (*Eumeces quinque-*

lineatus), as it is frequently called, is found from New York westward, increasing in abundance toward the South. In young specimens the body is black with vivid, longitudinal, yellowish stripes and a blue tail. As the animal becomes older, the body becomes a uniform dull olive brown; and the head turns to red. The adult attains a length of almost ten inches.

The glass snake, about which there are some weird superstitions, is an inhabitant of eastern United States from North Carolina southward. The glass snake is really a lizard, belonging to the family *Anguidae*. Its body is slender, elongated, and serpentine; and no traces of limbs are present. It can be distinguished from a snake by the presence of ear openings and by the presence of well-developed eyelids. The underside also lacks the transverse scales or scutes which are present on all snakes. The ventral surface is covered with numerous rows of smooth, overlapping scales which are of no use in locomotion. The back scales are arranged in ring-like rows. The color is a dark, olive brown above with bright green spots within each scale. There are thin lines on the neck. The underside is a uniform greenish white. Locomotion is effected by undulating the body from side to side.

There is a fold on each side of the body, extending from the head to the base of the rounded tail, which is two-thirds of the total body length. The glass snake is a burrowing species. It feeds chiefly upon earthworms and insect larvae, although it is reputed to break the eggs of ground-nesting birds and lap up their contents. There is an old and widespread superstition that the glass snake can be broken into many parts and that these parts will migrate together and form a whole animal again. This idea probably arose from the fact that the glass snake can shed its tail of its own accord, while with many other lizards the tail is brittle and breaks off only when held by another animal.

The gila monster (*Heloderma suspectum*) is the only poisonous lizard in the United States. It is found only in the deserts of Arizona and New Mexico, but because of its virulence and brilliant colors it is fairly well known throughout the country. The body of the gila monster is covered with bead-like tubercles which take the place of the ordinary scales. The body is broad and stout with short, robust limbs. The color pattern is quite variable, but it consists of a bright salmon or yellowish pink with irregular markings of black. The legs and snout are mostly black. The gila

monster is a vicious lizard with a number of grooved teeth on each side of both jaws. The poison glands are swollen salivary glands in the chin. When the lizard bites, it hangs on with the tenacity of a bulldog or a snapping turtle. It does not let go; and as it holds on, the grooves of the teeth conduct the poisonous saliva into the wound made by the teeth. The gila monster is oviparous and deposits its eggs in excavations in the sand. It belongs to the family *Helodermatidae.*

The horned lizards are generally known as "horned toads," and they are inhabitants of the dry, sandy sections in Texas, Arizona, the Southwest, and the Far West (Fig. 164). They differ greatly from other lizards in that they have broad, flattened bodies and comparatively short tails. Their bodies are covered with minute granular scales among which there are vertical, sharply pointed spines. The head is covered with projecting spines which give to the animals a grotesque and formidable appearance. However, the "horned toad" is one of the most docile of lizards and it rarely bites. It is active during the hottest part of the day when most other animals have retired to shelter from the intense rays of a desert sun. At night the horned toad lies buried in an excavation of its own making, with its body covered and only its eyes and the top of the head exposed. The coloration is protective. The lizard feeds entirely upon insects which it captures with a long tongue, in much the same manner as do toads. Other lizards usually stalk their prey, but the horned toad depends upon the lightning action of its tongue for capturing food. Unlike the other lizards, the horned toad is viviparous.

One of the most remarkable defense mechanisms in nature is to be found in the horned toad. In some species, at least, the creature when captured will violently emit a stream of blood from the corners of its eyes. There are many species of horned toads, but all of them have, in general, the same characteristics which make them readily identifiable. The Texas horned toad, *Phrysonoma cornutum*, is a typical horned lizard.

4. **Crocodiles and alligators.** The alligators and crocodiles are becoming increasingly scarce in the United States due to the fact that since their discovery they have been slaughtered in countless thousands either for sport or for their hides. The alligator is found only in America and in China, while the crocodile has a discontinuous distribution, being found in Africa, India, and

tropical America. At the present time the crocodile is found only at the southern end of the Florida peninsula, while the alligator ranges from South Carolina southward to Florida and westward to Texas. Western Louisiana is almost the western extremity of its range, however.

The alligator is not such a dangerous beast as is commonly supposed, although it can be formidable when irritated. It is

Fig. 195. The Florida alligator in its natural haunts. From an exhibit in the Carnegie Museum.

probably most common in Florida at the present time, particularly in the Everglades (Fig. 195). The writer saw several specimens recently, and at one place he found the skeletons of seven animals which were from three to four feet in length. These skeletons were in a heap on a small island in the Everglades; and they had evidently been captured and devoured by some other animals, probably birds. Large specimens are seldom encountered, although in some of the Seminole Indian villages there are some very large animals in captivity.

Young alligators are purchased by the thousands in Florida by tourists and these are sent to all parts of the country. The great majority of them are allowed to die of starvation or from cold.

The crocodile differs from the alligator in having a much more pointed head and snout. Both of them have raised eyes so that they can rest just beneath the surface of the water with only their nostrils and eyes protruding. The crocodiles and alligators have powerful jaws, and both are entirely carnivorous. The crocodile frequently buries its food and allows it to partly disintegrate before eating it. The crocodile is much more agile and aggressive than the alligator, and the African crocodile is a dangerous creature to encounter. Both the alligator and the crocodile lay large, white, hard-shelled, oval eggs which they place under heaps of débris.

BIBLIOGRAPHY

Reptiles

Agassiz, Louis, *Turtles.* Contrib. to Nat. Hist. of U. S., No. 1, 1857.

Babcock, H. L., *The Turtles of New England.* Memoir Boston Soc. Nat. Hist., Vol. 8, 1919.

Bishop, S. C., *The Amphibians and Reptiles of Allegheny State Park.* N. Y. State Mus. Handb., No. 3, 1927.

Blanchard, F. N., *A Key to the Snakes of the United States, Canada, and Lower California.* Mich. Acad. Sci. Arts and Letters, Vol. 4, Pt. 2, 1925.

——, *A Revision of the King Snakes, Genus Lampropeltis.* Bull. 114, U. S. Nat. Mus., 1921.

Boulenger, E. G., *Reptiles and Batrachians.* Dutton, 1914.

Camp, C. L., *Classification of the Lizards.* Bull. Amer. Mus. Nat. Hist., XLVIII, 1923.

Clark, A. H., *Animals of Land and Sea.* Van Nostrand, 1927.

Cope, E. D., *A Critical Review of the Characters and Variations of the Snakes of North America.* Proc. U. S. Nat. Mus., Vol. XIV, 1892.

——, *The Crocodilians, Lizards, and Snakes of North America.* Ann. Rep. U. S. Nat. Mus., 1898.

Ditmars, R. L., *Snakes of the World.* Macmillan, 1931.

——, *The Reptile Book.* Doubleday Doran, 1908. Well illustrated and interesting accounts of the turtles, tortoises, crocodilians, lizards, and snakes which inhabit the United States and northern Mexico.

Dunn, E. R., *A Preliminary List of the Reptiles and Amphibians of Virginia.* Copeia, No. 53, 1918.

Dunn, E. R., *Reptiles and Amphibians Collected in the North Carolina Mountains, with Special References to Salamanders.* Bull. Amer. Mus. Nat. Hist., Vol. XXXVII, 1917, p. 593.

Fowler, Henry W., *The Amphibians and Reptiles of New Jersey.* Ann. Rep. N. J. State Mus., 1906.

Gadow, Hans, *Amphibia and Reptiles.* Cambridge Nat. Hist., VIII, London, 1901.

Garman, H., *A Synopsis of the Reptiles and Amphibians of Illinois.* Bull. Ill. State Lab. Nat. Hist., Vol. III, 1892, Article XIII.

Hay, Oliver Perry, *Batrachians and Reptiles of Indiana.* 17th Rep. Geol. Sur., 1892, p. 412.

Hegner, R. W., *College Zoölogy.* Macmillan, 1933.

——, *The Parade of the Animal Kingdom.* Macmillan, 1935.

Hurter, Julius, Sr., *Herpetology of Missouri.* Trans. Mo. Acad. Sc., Vol. 20, St. Louis, 1911.

Jordan, David Starr, *Manual of the Vertebrate Animals of the Northeastern United States.* World Book Co., 1929.

Morgan, Ann, *Field Book of Ponds and Streams.* Putnam, 1930.

Netting, M. G., *The Poisonous Snakes of Pennsylvania.* Carnegie Mus. Vert. Zoöl. Pamph., 1932.

Ortenburger, A. I., *Whip Snakes and Racers.* U. of Mich. Stud., Vol. I, 1928.

Paulmeier, Frederick, *New York Reptiles and Batrachians.* Bull. 51, N. Y. State Mus., 1902.

Pratt, H. S., *A Manual of Land and Fresh Water Vertebrate Animals of the United States.* Blakiston, 1923.

Reese, Albert M., *The Alligator and Its Allies.* Putnam, 1915.

Ruthven, A. G., Thompson, C., and Gaige, H. T., *The Herpetology of Michigan.* Mich. Handb., Ser. 3, 1928.

Ruthven, A. G., *The Reptiles of Michigan.* Mich. Geol. Biol. Sur. Publ. No. 10, 1912, p. 63.

——, *Variations and Genetic Relationships of the Garter Snakes.* U. S. Nat. Mus. Bull. 61, 1908.

Stejneger, Leonard, *The Poisonous Snakes of North America.* Rep. U. S. Nat. Mus. for 1893.

Stejneger, Leonard, and Barbour, T., *A Check List of North American Amphibians and Reptiles* (2nd edition). Harvard Univ. Press, 1923.

Stone, Witmer, "Notes of the Reptiles and Batrachians of Pennsylvania and New Jersey," *Amer. Nat.*, Vol. 40, 1906, p. 159.

Strecker, J. K., *Reptiles and Amphibians of Texas.* Baylor Bull. XVIII, 1915, No. 4.

Surface, Harvey A., *Lizards of Pennsylvania.* Zoöl. Bull. State Dept. Agric., Vol. 5, 1907, p. 236.

Surface, Harvey A., *Serpents of Pennsylvania.* Zoöl. Bull. State Dept. Agric., Vol. 4, 1906, p. 115.

——, *Turtles of Pennsylvania.* Zoöl. Bull. Dept. Agric., Vol. 6, 1908, p. 107.

Viosca, Percy, Jr., *A Contribution to Our Knowledge of the Water Snakes.* Contr. No. 2, Research Dept., Southern Biol. Sup. Co., Inc., 1924.

——, "The Tale of 'Old Fire Eyes,'" *Nat. Hist.*, Vol. XXV, 1925, No. 4.

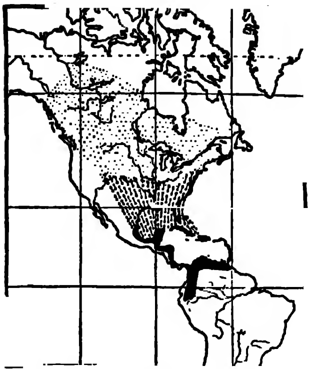
CHAPTER XVIII

THE STUDY OF BIRDS

No other group in the animal kingdom has commanded the interest of nature-lovers as have the birds. Thousands of persons everywhere have pursued bird studies as a hobby, and the birds have won the hearts of young and old alike. Through the education of the masses to the beneficial and esthetic values of birds, there is now an almost universal spirit of protection for them. Audubon societies and bird and nature clubs are numerous in every land. As a result of mass interest in birds, state, federal, and international regulations have been adopted for their protection; and bird life is on the increase. Almost every city, town, and country district is populated with a sufficient number of species to make observational studies practicable. Almost any limited area is inhabited by a large number ranging from 75 to 300 species; but the observation of them requires time, patience, and carefully executed procedures. Their study is made easier by classifying them into habitat groups.

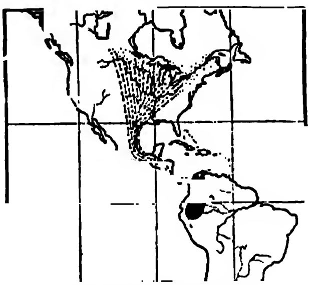
To attack the identification of a large number of species without any previous knowledge of their distribution or habitat selection will result in confusion. It is suggested that the student bear in mind that all of the native species of birds will not be seen in any one situation. There is a definite, horizontal distribution according to the nature of the landscape and a rather well-defined vertical distribution, particularly in forest areas.

Some species are indigenous to open fields (meadow lark, bobolink, vesper, grasshopper, savanna, field, and Henslow's sparrows, goldfinch, horned lark, quail, killdeer). Others are found along the thickets or at the edge of a wood (song sparrow, peewee, kingbird, catbird, wren, flycatcher, vireo, bluebird, chickadee, nuthatch, tree swallow, towhee, junco). Others inhabit the deciduous and evergreen forests (redstart, tanager, kinglet, wren, thrush, veery, ovenbird, creeper, titmouse, grouse, oriole, yellow-breasted chat, Maryland yellow throat, rose-breasted grosbeak, purple finch, crossbill, etc.). Another interesting assortment is to be found

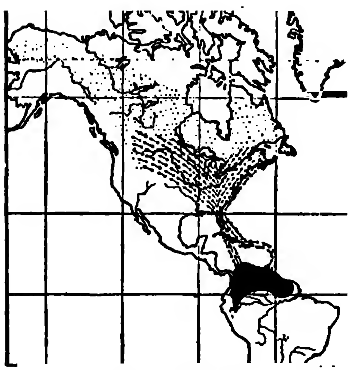


Redstart

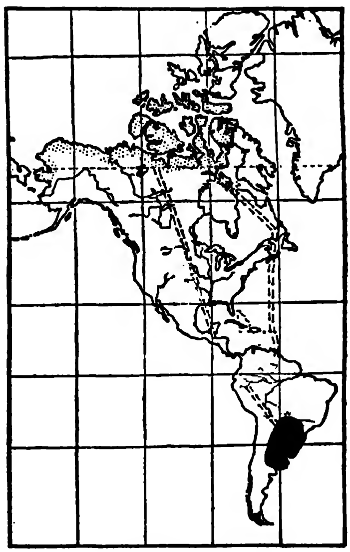
Bobolink



Mourning Warbler



Blackpoll Warbler



Golden Plover

PLATE XX. Maps showing the routes of migrations of various birds. Dotted area indicates breeding range; black area shows winter range; arrows show routes of migration. From Chapman, *Birds of Eastern North America*, courtesy D. Appleton-Century Co., Inc.

where lakes, ponds, and rivers exist (loon, coot, grebe, duck, goose, swan). One group is found in marshy regions (snipe, killdeer, woodcock, sandpiper, bittern, heron, marsh hawk, marsh wren, rail, swamp sparrow, yellow leg, plover, and red-winged blackbird); while still another group is seen most frequently in the air (hawk, eagle, vulture or "buzzard," swift, swallow, gull, tern). Some birds such as crows, quail, vesper sparrows, cowbirds, bobolinks, and grackles travel in flocks.

The student of birds will also soon observe that there is a rather obvious distribution of birds according to altitude. By altitude is meant vertical distribution. When the observer is aware that the place to see certain birds is on the ground and that others are to be looked for in the treetops, the study of them is made easier. While there is no fixed distribution of birds according to altitude zones, there is, nevertheless, a quite definite stratification which is of value in field studies.

On the ground stratum are to be found the nests of the meadow lark, towhee, ovenbird, whip-poor-will, thrasher, ground sparrow, white-throated sparrow, hermit thrush, veery, woodcock, quail, grouse, and others. In the undergrowth, from the ground to a height of about five or six feet, one can expect to find the nests of the chat, Maryland yellow throat, mocking bird, chestnut-sided warbler, catbird, and various others. There are, of course, many variations of the usual nesting habits.

On the lower branches of the trees and in the higher shrubs the nests of vireo, warbler, cardinal, cuckoo, mourning dove, chipping sparrow, waxwing, goldfinch, song sparrow, kingbird, and house-wren can be found. Up in the treetops there is an assortment of highly colored species that seldom descend to the lower levels. Among these are orioles, purple finches, wood peewees, cerulean, pine, blackburnian and other warblers, and the hawks, crows, and eagles. By recognizing the zonation of native species, the large representative fauna is split into smaller groups which render field studies considerably less difficult.

Bird study should not be confined to a single season but should continue throughout the entire year. The bird calendar will reveal many species that can be seen only at certain times. In every region there is a rather large group of winter residents which are only a fraction of the total population of the year. The winter is probably the best time of year to begin field studies because

at this time the number of birds is considerably reduced, and the beginner is not confused by numerous species. Then, too, most of the trees and shrubs are leafless, and vision is not inhibited by great masses of foliage. No other season provides such splendid opportunities for seeing certain birds. Since food is rather scarce in winter, the birds are easily attracted to feeding shelves, drinking pans, and lumps of suet. *The Book of Bird Life* by Allen gives a splendid treatise on how to attract birds.[1]

At the first outburst of spring, the return of the summer contingent begins; and the early spring is also an excellent time to study birds. The species appear a few at a time until May, when the amateur is overwhelmed with numbers. Many of these species, however, will not remain. They only pause in their northward migration to feed and rest, and in a week or so they leave. In almost any region there are many of these migrating species, and in many cases the few days in the migration period are the only opportunities for observing them. In this period a region has a larger bird population than it has at any other time of the year because many of the spring visitants do not stop in their return journeys in the fall.

After the departure of the visiting species, the number is reduced; and the summer residents which remain take possession of the countryside. They immediately begin the processes of courting, mating, and nest-building; and the air is filled with song. It is in this period that the activities of birds are most interesting, and their colors are the brightest.

A carefully kept bird calendar will, after a few years, show the permanent residents, winter residents, spring visitants, summer residents, and fall visitants. It will also enable one to predict, with a degree of certainty, the dates of arrival and departure of each species. In almost every community these records are available to those interested in making bird studies, and they greatly facilitate in establishing identities. Magazines such as *Bird Lore*, *The Auk*,[2] *The Wilson Bulletin*,[3] *The Condor*,[4] and local nature club and Audubon society publications will prove of great value in bird studies.

[1] Other sources are listed in the bibliography at the end of this chapter.

[2] *The Auk* is the official organ of The A. O. U.

[3] The Wilson Ornithological Club, Oberlin, Ohio.

[4] *The Condor* is the publication of the Cooper Ornithological Club, Pasadena, California.

Field studies. Bird studies in the field are slow, and certainly they are not easy. The student cannot expect to learn to know all of the native birds in a short time. It will take years of observation to become completely familiar with the bird life of a region. This, however, provides an excellent, permanent, inspiring, and recreational hobby for the student teacher or professional or business man. It is, for that matter, a wholesome and healthful pastime for anyone, and it will provide an excellent extracurricular activity for school children. It should help to solve the problem of the leisure hour and divert youth from questionable forms of entertainment. Moreover, the study of birds will contribute much to character-building; and it will develop a love for beauty in music, art, and social life. Class field trips are worth while provided that class interest has been stimulated and provided that the group is well disciplined in the necessary rules for bird observation. A noisy group, flashing a riot of color, will drive the birds as far away as possible; and the trip will degenerate into a walking trip with discouraging results. Bird studies in the field should be largely an individual matter, although well-disciplined classes can make many observations.

Each student should be equipped with a pair of field glasses. Inconspicuous clothing should be worn, and progress should be slow and quiet. Early morning is the best time for bird study. It is best to proceed cautiously to some quiet, well-protected spot and wait patiently. The birds will soon resume activity, and many of them will approach within range of the field glasses and pause long enough for thorough observations.

Bird descriptions. Before going into the field, the student should be familiar with the common bird orders and their outstanding characters. To properly describe a bird it is necessary to become familiar with the terminology used in bird description. Figure 196 represents the topography of a bird. It is used primarily for color descriptions. This should be copied in the field notebook for reference. To become familiar with bird description it is advisable to describe a number of common birds in terms of the topography in order to become familiar with their features. These descriptions can be made from mounted specimens in a museum collection, from bird skins, or from colored plates in bird books.[1]

[1] *The Perry Bird Pictures* (Perry Pictures Corporation, Malden, Mass.). Audubon charts and bird pictures used in advertising sewing machines, baking soda, etc., can also be used.

In addition to the color characters, the size of the bird and the structural features mentioned in the descriptions of the orders should be supplemented by the suggestions given a little later. All of these should be included in the field descriptions. This is the quickest and easiest way to learn how to properly describe a bird in the field. Of course all of the 23 characters on the chart are not necessary for each bird. Usually two or three of these

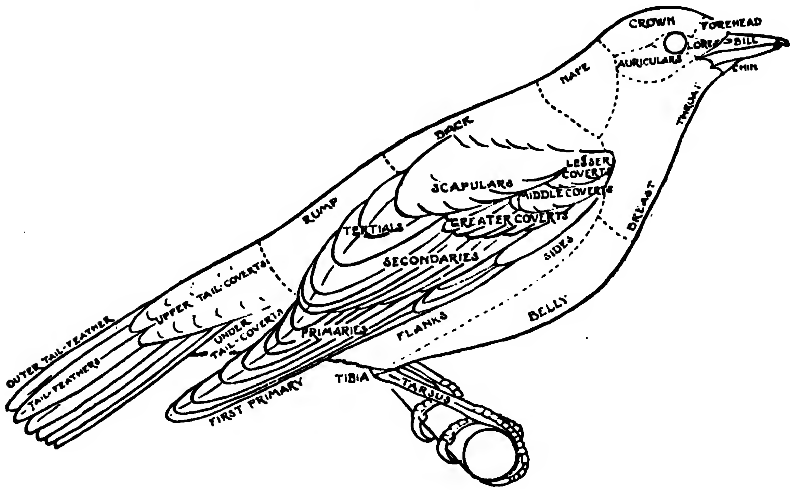


FIG. 196. The topography of a bird (for field descriptions). Courtesy Gen. Biol. Supply Co.

characters are all that are necessary, but the characters will be different for every species; hence it is imperative that all of them be learned. After a little practice in bird description the student will unconsciously pick up various little tricks in observation which will enable him to identify a bird in a flash. Such characters as size of bird, position of legs, relative sizes of feet and wings, characters of wings, feet, bill, and tail, flight mannerisms, signal markings, habitats, behaviorisms, and others will soon become the bases of numerous specific identifications. The experienced observer will unfailingly identify a species in an instant; but when pressed for an explanation of how he identified it, he sometimes has difficulty in explaining how he did. But in the beginning he had to go through all the details of topographical description, and his "ornithological sense" is the result of possibly hundreds of observations on a single species.

FIG. 197. Birds of the woodlands and woodland borders. (See caption on facing page.) From Allen, *The Book of Bird Life*, courtesy D. Van Nostrand Co., Inc.

Ground-Nesting Birds:

1. Woodcock
2. Bob-White
3. Ruffed Grouse
4. Whip-Poor-Will
5. White-Throated Sparrow
6. Junco
7. Pine-Woods Sparrow
8. Towhee
9. Black and White Warbler
10. Nashville Warbler
11. Oven Bird
12. Canadian Warbler
13. Veery
14. Hermit Thrush

Birds of the Undergrowth and Low Bushes:

15. Field Sparrow, and Yellow-Breasted Chat
16. Song Sparrow
17. Cardinal
18. Indigo Bird
19. White-Eyed Vireo
20. Black-Throated Blue Warbler
21. Chestnut-Sided Warbler
22. Mourning Warbler
23. Hooded Warbler
24. Mockingbird
25. Catbird, and Brown Thrasher
26. Winter Wren

Birds of the High Bushes and Lower Branches:

27. Mourning Dove
28. Black and Yellow-Billed Cuckoos
29. Kingbird
30. Acadian Flycatcher
31. Bluejay
32. Chipping Sparrow
33. Goldfinch
34. Rose-Breasted Grosbeak
35. Scarlet Tanager
36. Cedar Waxwing
37. Red-Eyed Vireo
38. Blue-Headed Vireo
39. Yellow Warbler
40. Magnolia Warbler
41. Myrtle Warbler
42. Redstart
43. Golden-Crowned Kinglet
44. Wood Thrush
45. Robin

Birds of the Higher Branches and Tree Tops:

46. Herons, Great Blue and Black-Crowned Night
47. Bald Eagle
48. Hawks, Red-Shouldered, Red-Tailed, Broad-Winged, Goshawk, Cooper's and Sharp-Shinned, Osprey
49. Olive-Sided Flycatcher
50. Wood Pewee
51. Baltimore Oriole
52. Purple Finch
53. Pine Siskin
54. Yellow-Throated Vireo
55. Warbling Vireo
56. Cerulean Warbler
57. Black-Throated Green Warbler
58. Blackburnian Warbler
59. Pine Warbler

Birds That Nest in Holes:

60. Wood Duck
61. Barn Owl
62. Barred Owl
63. Screech Owl
64. Great Horned Owl
65. Woodpeckers, all species
66. Crested Flycatcher
67. Sparrow Hawk
68. Starling
69. House Sparrow
70. Tree Swallow
71. Prothonotary Warbler
72. Carolina Wren
73. Bewick's Wren
74. House Wren
75. Brown Creeper
76. White-Breasted Nuthatch
77. Red-Breasted Nuthatch
78. Brown-Headed Nuthatch
79. Tufted Titmouse
80. Chickadee
81. Bluebird

Classification. A list of the orders with their most obvious characters briefly stated is given below.[1] The names in parentheses are the older classification which is still in use to an extent, and which is commonly found in the older bird books.

The student of birds should become familiar with the common bird orders and their distinguishing characteristics. In fact this is necessary in order to place a bird where it properly belongs, and it is the first step in determining new identities. Each order has, as a rule, a number of families, all of which are interesting but too numerous to learn. However, in the order of perching birds there are so many different kinds of birds, exhibiting a wide assortment of minor modifications and habits, that family groups should be learned. After all, it is interesting to know that crows and jays belong to the same family as do orioles and blackbirds; and until recently the robins, thrushes, and bluebirds were also grouped together.

The orders are as follows:

(1) *Gaviiformes* (*Pygopodes*). Aquatic diving birds with the webbed feet placed back near the posterior end of the body. Sharply pointed. Tail almost wanting. The loons (great northern diver and ruby-throated loons).

(2) *Colymbiformes* (*Pygopodes*). The smaller aquatic divers. Long-necked, lobed or web-footed, toes flat, feet at rear of the body. Grebes (pied-billed grebe and horned grebe, both much smaller than the loon).

(3) *Procellariiformes* (*Tubinares*). Bill hooked, hawk-like, the upper mandible enlarged at tip; nostrils open through tubes; feet webbed; hind toe reduced or wanting. Birds of the sea, including petrels and albatrosses.

(4) *Pelicaniformes* (*Steganopodes*). Pelicans, gannets, and cormorants. Totipalmate swimmers with all four toes webbed.

(5) *Anseriformes* (*Anseres*). Duck-like birds with four toes, the front ones webbed; flattened bills with tooth-like projections, ridges, or grooves on the sides. Ducks (many species), geese (two common species), swans (two common species).

(6) *Ciconiiformes* (*Herodiones*). Wading birds with long bare legs; four toes all on the same level, slightly or not at all webbed;

[1] The classification listed here is based on the 1926 report of the A. O. U. committee appointed to revise the classification of birds. The summary of characters is a modification of those in the appendix of Chapman's *Bird Life*.

neck much lengthened; eyes back on head; lores usually bare. Great blue heron, green heron, little blue heron, American bittern, least bittern.

(7) *Falconiformes* (*Raptores*). Diurnal birds of prey with the upper mandible hooked; nostrils opening in a cere; head slender; all four toes armed with strong, sharp, curved talons; hind toe, except in vultures, as long as shortest front toe; flight rapid; plumage stiff and brittle. Hawks and eagles.

(8) *Columbiformes* (*Columbae*). Four toes on same level, hind toe almost as long as shortest front toe; bill slender and grooved; nostrils open through a fleshy mass or cere. Doves and pigeons.

(9) *Galliformes* (*Gallinae*). Scratching birds with four toes, three in front and one behind; hind toe short and raised above the level of the others; bill hard and horny; wings comparatively short; feet and legs sturdy; outer primaries curved and stiffened. Chickens, turkeys, pheasants, quail.

(10) *Gruiformes* (*Paludicolae*). Running birds with four toes; hind toe small, sometimes higher than front toes; bill short and stout; forehead has a bare shield; lores feathered or with bristles. Cranes, rails, coots.

(11) *Charadriiformes* (*Limicolae*). Shore birds with four or three toes, hind toe when present is much shorter than the shortest front toe, and elevated; legs long and slender; lower half of tibia bare; wings long and pointed; bill in the snipe very long and flexible. Snipes, sandpipers, plovers, gulls, terns, phalaropes, jacanas, auks, murres.

(12) *Cuculiformes* (*Coccyges*). Strong-billed birds with four toes, two toes in front and two behind; the toes fused together (zygodactylus); tails long. Cuckoos (yellow- and black-billed cuckoos) or "rain crows" and allies.

(13) *Coraciiformes* (*Coccyges*). Long, prominent bill; large head; feet syndactylus, small and short; head with crest. Kingfishers.

(14) *Caprimulgiformes* (*Macrochires*). Pointed-winged birds with small, weak feet; bill short and shallow; mouth quite large; long bristles on either side of the bill; plumage soft. Whip-poor-will, night hawks.

(15) *Micropodiiformes* (*Macrochires*). Pointed-winged birds with small, weak feet. Bill short, shallow, wide in swifts; but very long, slender, and needle-like in humming birds. Chimney swifts, humming birds.

Yellow-Bellied Sapsucker

Robin

Brown Thrasher

Sparrow Hawk

Bluejay

Phoebe

Red-Wing Blackbird

Plate XXI. Some common birds. Sparrow Hawk after Sutton; all others after Judd, Bull. 17, courtesy Bur. Biol. Surv., U. S. Dept. Agric.

(16) *Strigiformes* (*Raptores*). Nocturnal birds of prey; large, broad head; eyes large; no neck; upper mandible strongly hooked; four toes, one reversible, all armed with long, curved talons; feet adapted for seizing; plumage soft, downy. Owls.

(17) *Piciformes* (*Pici*). Pecking birds with long, pointed bills; feet zygodactylus, the first and fourth toes directed backward; a long and a short toe in front and behind; tail feathers pointed and stiffened; tongue spear-shaped, barbed. Woodpeckers, flickers, or "yellow hammers," and sapsuckers.

(18) *Passeriformes* (*Passeres*). Perching birds with four toes, three in front and one behind, all on same level; hind toe as long as the middle front toe and equipped with long nail.

More than 75 per cent of the birds one sees in inland localities belong to this order, which includes 25 families as follows: (1) cotingas (*Cotingidae*) (rare in North America), (2) flycatchers (*Tyrannidae*), (3) larks (*Alaudidae*), (4) swallows (*Hirudinidae*), (5) crows, magpies, and jays (*Corvidae*), (6) titmice (*Paridae*), (7) nuthatches (*Sittidae*), (8) creepers (*Certhiidae*), (9) wren-tits (*Chamaeidae*), (10) dippers (*Cynclidae*), (11) wrens (*Troglodytidae*), (12) thrashers, catbirds, and mockingbirds (*Mimidae*), (13) thrushes, robins, and bluebirds (*Turdidae*), (14) kinglets and gnatcatchers (*Sylviidae*), (15) pipits and wagtails (*Motocillidae*), (16) waxwings (*Bombycillidae*), (17) silky flycatchers (*Ptilogonatidae*), (18) shrikes or butcher birds (*Laniidae*), (19) starlings (*Sturnidae*), (20) vireos (*Vireonidae*), (21) honey creepers (*Coerebidae*), (22) wood warblers (*Mniotiltidae*), (23) blackbirds, orioles, and meadowlarks (*Icteridae*), (24) tanagers (*Thraupidae*), (25) finches, sparrows, grosbeaks, and crossbills (*Fringillidae*).

It has been suggested that the field identifications are difficult, and only repeated observations will establish identities. If a student learns to positively identify 25 birds in the field in a year's time, he is doing very well. At any rate he will see many species that he does not know. However, he should get some pleasure out of being able to place the unknown bird even in its proper Order.

Structure of the Body

But bird studies must go much further than mere identities. ***Every bird should be of interest, whether its identity is known or not,*** and *it will be* if the principles of adaptation are learned and applied. These enable one to interpret a bird in terms of its environment,

and a little experience will develop an ability to determine the food and flight characters of almost every bird observed, even though the identity is not known. These are all revealed by the modifications of the bird's body structures—bill, feet, wings, and tail.

The bill. The bill or beak is composed of two mandibles, upper and lower. These are always adapted to special feeding habits

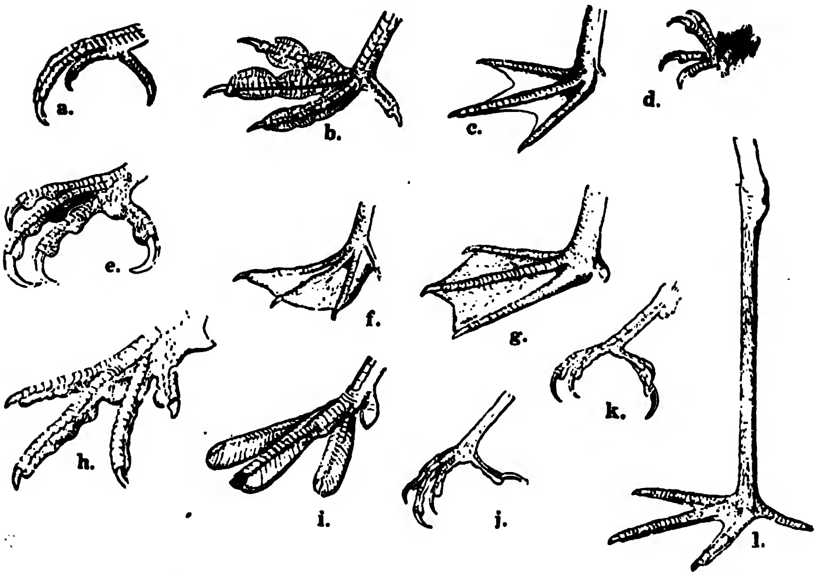


FIG. 198. Adaptive modifications of the feet of birds. a. Perching foot of a kingfisher; b. Foot of a coot with expansions for walking on mud; c. Wading foot of avocet; d. Clinging foot of a swift; e. Seizing foot of a hawk; f. Swimming foot of the tropic bird; g. Swimming foot of a duck; h. Scratching foot of a pheasant; i. Foot of a grebe adapted to swimming under water; j. Foot of a perching bird; k. Woodpecker foot for climbing vertical surfaces; l. Foot of a wading bird. From Hegner after Sedgwick's *Zoölogy:* c., f., h., j., k. after *Règne animal.*

and indicate the principal food of the bird. Everyone knows that the hooked upper mandible of the hawks, owls, and eagles is adapted to tearing flesh, indicating predatory habits.

The long, strong, pointed bills of the woodpecker, flicker, and sapsucker are well adapted to boring into trees. Incidentally, the woodpecker has a spear-shaped tongue with backward-pointing barbs. When the burrow of a wood boring insect is reached, the

tongue is inserted; and the barbed tongue rakes out the insect inhabitants.

The long, slender, needle-like bill of the humming bird suggests a piercing habit. The bird is too heavy to alight on the flower, so it hovers over it and inserts its sharp bill into the flower cup and punctures the nectar glands. The doubly tubed tongue sucks the

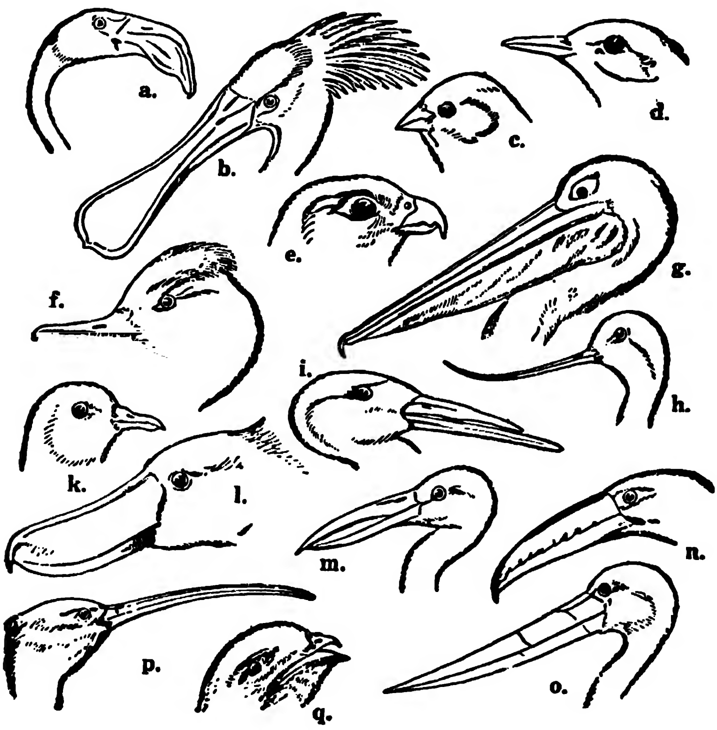


FIG. 199. The most important forms of birds' beaks. a. Flamingo; b. Spoonbill; c. Yellow bunting; d. Thrush; e. Falcon; f. Duck; g. Pelican; h. Avocet; i. Black skimmer; k. Pigeon; l. Shoebill; m. Stork; n. Aracari; o. Stork; p. Bird of paradise; q. Swift. From Hegner after Sedgwick's *Zoölogy:* a., b., c., d., k. after Naumann; g., i., m., o. after *Règne animal;* l. after Brehm.

nectar and then sweeps out the small insects that are usually seen in flowers. Some fish-eating birds, like the kingfisher, have spear-like bills for harpooning their victims.

The seed-cracking and bud-eating birds like the finches, sparrows, and grosbeaks have large, deep, short, and hard bills. Some types of bills are shown in Fig. 199.

The insectivorous birds such as flycatchers, catbirds, wrens, etc., have long, slender, shallow bills; and the upper mandible has a small, sharp hook at the tip for crushing the chitinous bodies of insects. Some of these birds such as creepers have very slender bills which may be inserted into crevices in bark where smaller insects hide.

An extremely long bill like that of the snipe is suggestive of probing habits and indicates insertion. On the snipe it is used for feeding on animals which live in the mud. The upper mandible is soft, flexible, and movable so that at each insertion the bird can feel around. This reduces the number of insertions necessary for securing a meal.

Chimney swifts, swallows, and whip-poor-wills feed on the wing, usually with the mouth open. These birds have a wide, short, and shallow bill which increases the gape. The large mouths enable them to sweep insects from the air.

The ducks and geese, which frequently secure their food under water, have spoon bills with rows of marginal teeth. When mouthfuls of bottom material are taken, the teeth allow the water to drain out; and they strain the solid matter from the water.

There are frequently bills which exhibit both insectivorous and seed-eating characters (e.g., grackle), and these are indicative of omnivorous habits.

One of the most remarkable bills is that of the American crossbill which is well adapted to extracting the seeds from the cones of pines and other evergreens. In this bird the mandibles are curved and cross each other like a pair of scissors.

Most of the insectivorous birds are forced to migrate in winter when insect activity has ceased; but those which have bills adapted to reaching in crevices of bark, to tearing cocoons, plucking scale insects and the tiny eggs of plant lice from the twigs are able to survive the winter months; and it is not necessary for them to migrate. These constitute a large percentage of winter residents and include titmice, chickadees, creepers, nuthatches, downy and hairy woodpeckers, golden-crowned kinglets, winter wrens, and bluejays.

The seed-eating and bud-eating birds including redbirds or cardinals, certain sparrows, goldfinches, purple finches, crossbills, and juncos are able to secure enough food from weeds, berry bushes, and trees to tide them over. Of course a bird's diet is not

invariable; and even the English sparrow with a seed-cracking bill does not hesitate to gobble down a luckless fly or measuring worm, should it get too close; and young sparrows are fed soft insects until their bills harden sufficiently to crack seeds.

The feet and legs. When one sees a bird with long, bare legs, like those of the heron, he recognizes it immediately as a wader. It must necessarily have a long neck, and usually it has a long bill to insert in the water. Its eyes are further back on the head, and the lores are bare. The toes are long so as to distribute the weight and prevent the bird from sinking into the mud.

The webbed feet of ducks and geese immediately indicate swimming; and the coots, grebes, etc., with their flanged or lobed toes, show adaptation to walking on mud.

The grasping feet of the hawks, owls, and eagles, with their long talons, clearly enough suggest their use. The vultures, which are also birds of prey, feeding only on dead animals, do not have to pursue and capture their victims; and they, therefore, have lost the grasping feet although they still retain the hooked bill.

The large, well-developed feet of chickens, turkeys, and pheasants indicate that these birds spend most of their time on the ground. The hind toe is short and elevated so as not to interfere with their scratching. In winter the grouse develops feather-like or comb-like projections along the toes which enable the bird to walk on snow by producing a snowshoe effect.

The woodpeckers are able to cling to vertical surfaces by means of their modified feet which have the toes arranged two in front and two behind. Perching birds have their toes all on the same level, with the hind toe quite long and bearing a large nail. This arrangement enables them to clasp a perch.

The small weak feet of swifts and humming birds indicate that they spend considerable time on the wing. Some types of birds' feet are shown in Fig. 198.

The wings. While the wings are primarily organs of flight, they sometimes are used for other purposes. In the ruffed grouse they are used as musical instruments. This bird has no call and resorts to "drumming" with its wings. In reality the wings do not strike the log on which the bird chooses to disport itself, the sounds being made entirely by fanning the air with the wings. The woodcock, too, uses its wings in such a manner as to produce peculiar sounds when courting. Frequently the wing is the seat of sexual

adornment, and the male spreads his wings and displays all of the colored feathers when courting.

Among many birds the wings are used as organs of defense, and anyone who has encountered a hen with chicks or who has run afoul of a goose knows that these birds can very effectively beat off an intruder with their wings.

In South America there is a bird called the hoactzin, the young of which has a finger-like claw or hook on the thumb and first finger of the wing by means of which it climbs about over the branches.

The gallinules also have a small spur on the wrist which young birds use to assist them in making a getaway through the reeds.

The penguins of the Antarctic, having few enemies, have lost their ability to fly; and the wings have become modified into paddles or flippers by means of which they are able to swim. The penguins being typically aquatic diving birds have their feet at the rear of the body so that when walking on land their bodies are nearly erect. When disturbed in their nesting places, these birds, in their haste to reach the water, use their modified wings as front legs. The size and shape of the flying wings are indicative of the flight habits of birds.

In this connection it might be well to discuss certain characters of flight and to point out some of the adaptive features which will prove of interest in making field observations.

The flight of birds and other animals. Flight ability is evidently associated with an ancestral adaptation to arboreal existence. It is of great advantage to animals in escaping from enemies, seeking food, migrating from unfavorable localities, and in the distribution of species. The ability of animals to remain in the air depends upon the two principal factors: (1) the ratio of the horizontal surface exposed to body weight, and (2) the rate of movement. Animals having considerable weight in proportion to horizontal surface cannot make long flights.

There are two kinds of flight, active and passive. Active flight is the effect of flight mechanisms involving propelling apparatus such as wings. Passive flight is effected by specialized attachments and modified appendages which assist organisms in remaining aloft. Hair tufts such as those on the seeds of goldenrod, wild lettuce, and milkweed; the wing structures on the seeds of the pine, ash, elm, and maple; the floating thread of the ballooning

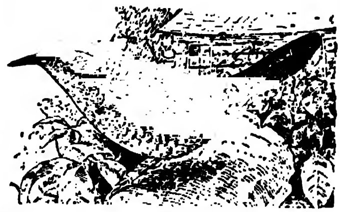
Chickadee

Starling

Bewick's Wren

Baltimore Oriole

Great Horned Owl



House Wren

Towhee or Chewink

Nests of the Bank Swallow

Red-Headed Woodpecker

Barn Swallow

Meadow Lark

PLATE XXII. Some common birds. Starling after Sutton; Bewick's Wren from Evans, *Birds*, courtesy The Macmillan Company; Great Horned Owl from Newman, *Vertebrate Zoölogy*, courtesy The Macmillan Company; all others from Judd, Bull. 17, courtesy Bur. Biol. Surv., U. S. Dept. Agric.

spider; the large, wing-like pectoral fins of flying fishes; the skin flaps of flying lizards and flying squirrels, etc., are all apparatuses for passive flight. Passive flight includes gliding or volplaning and soaring. Native birds are all capable of active flight in variable degrees, and a number of them are also capable of passive flight. In all cases there are specialized wing characters which enable one to recognize the more obvious flight habits of birds in general. Small birds have relatively larger wings than big ones. For each pound of body weight a swallow has a wing area of four square feet, 18 square inches; a pigeon has one square foot, 14 square inches; a stork has 122 square inches. But it is necessary for small birds to move their wings more rapidly. For instance, it has been found that a sparrow vibrates its wings 780 times per minute; a duck 540 times per minute; a crow 120 times per minute. It is more difficult for a heavy bird to get started; but when it does, it is easier for it to keep going. On the other hand, the heavy bird cannot stop so easily. A light bird can take off suddenly; it must keep vibrating its wings rapidly to keep going, although it can approach a perch at high speed and stop rather suddenly.

The comparatively short and rounded wings of chickens and grouse suggest that these birds spend most of their time on the ground and fly little. Such wings are moved rapidly and enable the birds to make a quick getaway; but so much energy is expended that they soon tire, and they can fly for only short distances. Other birds such as some flycatchers (kingbird) and hawks (Cooper's and sharp-shinned) which lie in wait for their victims have wings somewhat similar. But in the hawks that soar the wings are quite different. In these, as well as in vultures and eagles, the wings are large and very broad. Vultures (turkey buzzards) have been known to remain in the air for more than seven hours without flapping their wings. These soaring birds are supposed to utilize upward currents of air to hold them aloft (although this has been recently questioned); and they usually soar in circles. It is said that soaring for long periods is not possible on cloudy days or in cold weather. Soaring is possible only when the earth is heated by the sun's rays.

Gulls and terns have long, narrow wings; and they are able to remain in the air for many hours. Sometimes these birds are also able to take advantage of the upward air currents to keep

aloft, but as a rule they do not soar. The long, narrow wing is well adapted to gliding, however; and fish hawks, marsh hawks, and gulls frequently indulge in gliding or sailing although they cannot soar.

The chimney swifts, swallows, humming birds, whip-poor-wills, and numerous other birds have long, pointed wings. These birds cannot soar; but since most of them are active predators, they must be able to develop speed in order to overtake their victims. The pointed wings vibrate rapidly, and their possessors are usually excellent fliers.

The plumage of the wing may be harsh and stiff as in hawks, or it may be soft as in owls. The hawks are much more rapid fliers than the owls, and their wings make considerable noise in flight. The owl, lacking sufficient speed to overtake other animals, must silently sneak upon its victims.

With regard to the speed of flight, it has been found that a few birds have a flight capability of over 100 miles per hour; but it is usually much less. Homing pigeons may maintain a speed of 55 miles an hour for several hours, and herons have been known to fly at 35 miles per hour. Wild ducks and geese average about 50 miles an hour, but the smaller birds usually average about 30 miles per hour.

The tail. The tail serves many purposes among birds. On the average inhabitant of the trees the tail serves as a balancer while the bird perches. You have probably noticed the movements of the tail when a bird is perched on a swaying wire or twig.

In a number of birds there are vast differences in the tails of the sexes. In these cases the tail of the male is usually adorned and modified for courting. For instance, the peacock has a gorgeous tail of which he seems quite proud, and he does not hesitate to spread it in such a way as to reveal its splendor to the female. The turkey gobbler has a large, bedecked tail with which he attempts to win the favor of some less fortunate and unadorned turkey hen. In pheasants, game cocks, bantams, birds of paradise, and others, the tails of the males exhibit secondary sexual characters and are much more elaborate than in females.

In most birds the tail is used as a rudder in flight; and the most graceful fliers, such as swallows and terns, have long, forked tails which enable them to turn quickly to the right or left, which short-tailed birds cannot do.

The tail is used by practically all birds in stopping. The tail is directed downward and spread to its full extent in order to retard flight. Soaring birds have broad tails which increase the surface exposed.

On birds which cling to vertical surfaces the tail serves as a prop, and the feathers are usually pointed and stiffened. Woodpeckers, nuthatches, and creepers have tails like these. The chimney swift, however, which also uses its short tail as a prop, has bare, needle-like protrusions on the tips of the tail feathers. In water birds the tail is usually much reduced or apparently wanting.

There is considerable evidence that the white outer tail feathers, color bands, and other markings on the tails of some birds serve as recognition markings, by which they spontaneously recognize others of their kind.

The Colors of Birds

The colors of birds are probably responsible for stimulating the first interest in them. Certainly no other animal group exhibits, or carries so well, the coat of many colors so characteristic of birds. Coloration is usually structural, being due to the analysis of light by refraction and reflection through modification of the surface of feather structures. Thin films with striations and other markings are quite frequently responsible for the colors reflected (indigo bunting). Sometimes the color is the result of a combination of pigment and structural markings, especially blues and metallic colors. In a few cases the color is entirely due to pigment as in the scarlet tanager. There is considerable evidence to show that intensities of color in both birds and insects are largely due to conditions of humidity.

Abnormalities of color occasionally appear. Some of these are extremely dark coats exhibiting melanism, and an individual of a light-colored species may be almost black.

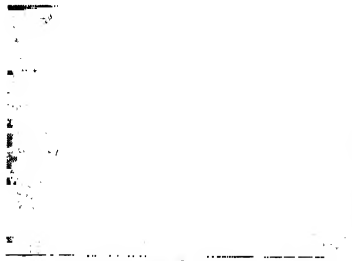
On the other hand, albinos not infrequently appear. These are just the opposite of melanic forms in which there is an excess of pigment. Albinos have a total lack of pigment and are therefore white. White crows, white blackbirds, white robins, and white wrens are frequently reported. Both melanism and albinism are genetic characters, and they are characteristic in numerous animal groups. Albinism is explained elsewhere.

As a rule among the brilliantly colored birds the gaudy coat is

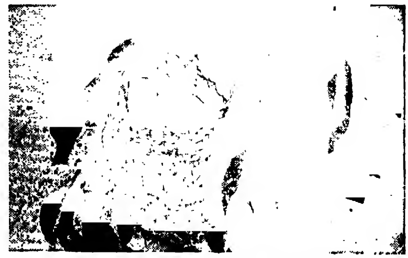
restricted to the male; or he is, at any rate, by far the more brilliant. This is true of the indigo bunting, goldfinch, scarlet tanager, red-winged blackbird, wood duck, and rose-breasted grosbeak. In many of these cases the male is brilliant only during the breeding season, after which the bird molts; and the new plumage is dull and does not contrast so noticeably with that of the female. In a few instances, such as among the phalaropes, the female is the brighter. The usual duller color of the female is of great advantage, since it is necessary for her to remain on the nest while laying eggs and during the incubation period. A brilliant coat would render her too conspicuous and subject her to too many dangers.

Among those species such as the red-headed woodpecker and the belted kingfisher, where the females are as gaudily colored as the males, the nest is usually concealed within a tree or an excavation in the ground; and the female may brood in comparative safety. Brilliantly colored birds are usually seen in more or less open places where enemies cannot lurk unseen, while those species which have protective coloration are inhabitants of the thickets, grasses, or the forest floor. Hence the goldfinch perches on the top of a tall weed, and the tanagers occupy the treetops; while the sparrows that feed on the ground have striped bodies (grass pattern), and the quail is mottled like a patch of dead leaves.

The young of most brilliantly colored birds are inconspicuously colored. The young of robins and bluebirds have mottled breasts like other thrushes, and lack the colors of the adults. The young male grosbeak lacks the showy colors of its father and more nearly resembles its duller-colored mother. The young kingfisher and the woodpeckers are exceptions, however. The colors of birds, in addition to those of courtship and sexual differences, are usually protective, although many of them appear conspicuous on close examination. Like most other animals the bodies of birds are counter-shaded. That is, they are dark on the back and lighter beneath. This is a camouflage quite general in nature and breaks the outline of the body since the light underside reduces shadows. The color markings are usually ruptive, mimicking, or concealing; and birds so marked almost invariably select habitats with suitable backgrounds for their activities. The grouse, quail, and woodcock with their patches of light and dark brown are inconspicuous on the ground in a woodland. The sparrows, female red-winged



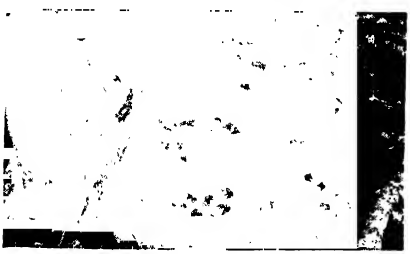
Robin's Nest on the Wheel of an Idle Tractor



Nest of the Orchard Oriole

Beach Nest of the Piping Plover

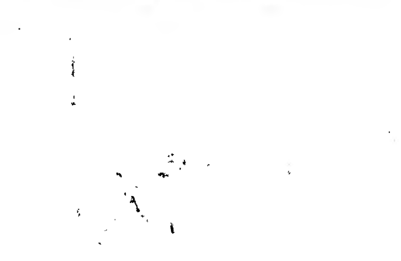
Nest of the Florida Gallinule



Nest of the Ruffed Grouse

Floating Nest of the Pied-Bill Grebe

Nest of the Ruby-Throated Humming-bird



Nest of a Tree Swallow in a Fence Post

FIG. 200. Types of birds' nests. Photographs by Reinhold Fricke, Carnegie Mus.

blackbirds, and meadow larks have the striped grass pattern. The screech owl is dimly visible when silhouetted against a tree trunk, and the short cross markings on the underside of a great horned owl make the bird almost invisible in a hemlock tree. The sandpiper and the plover which patrol the beaches are speckled so as to resemble the sand, and the killdeer has ruptive cross bands of black across the breast. The birds that lie in wait to capture insects on the wing are always dully colored and of such a hue as to make them pretty well resemble the background of foliage. Hiding in the recesses of the foliage, waiting for insects to pass at close range, the vireo and flycatcher would be too easily spotted by their victims were they gaily decked with colors.

The whip-poor-will, which crouches lengthwise on a dead log during the day, is difficult to see; while some birds, as the bittern, have long, slender necks and bills which they stretch upward so as to resemble reeds, when disturbed.

There seems to be no doubt that certain bands or spots are of value in assisting others of their kind in identifying them. The white rump of flickers and bobolinks; the white band across the wings and back of the red-headed woodpecker; the white outer tail feathers of juncos, vesper sparrows, chewinks, and meadow larks are all flash or signal markings which not only serve as identification characters for other birds, but they also assist the student to readily identify them. In addition they may be of value in confusing enemies and in signaling a warning to other birds that danger approaches. Some common species of birds are shown in Plates XXI, XXII, and XXIII.

THE FOOD OF BIRDS

The economic status of a bird is too frequently based upon a few inadequate observations of its feeding habits. Many of these observations are cursory and superficial, and they result in erroneous interpretations. The rose-breasted grosbeak has been one of the victims of such a procedure. It has been observed disturbing potato plants; and the observers accused it of destroying them when in reality the bird was seeking the larvae of the destructive potato beetle. For many years the rose-breasted grosbeak enjoyed a bad reputation and was persecuted for its activities until someone discovered its beneficial proclivities. It is now known as one of the few birds that will eat the potato beetle.

Cedar Waxwing

Mourning Dove

Rose-Breasted Grosbeak

Yellow-Billed Cuckoo

Flicker

Bobolink

King Bird or Bee Bird

Catbird

PLATE XXIII. Some common birds. After Judd, Bull. 17, Bur. Biol Surv., U. S. Dept. Agric.

The farmer who sees a blackbird in his cornfield does not stop to consider that the bird which does sometimes unearth planted corn also feeds upon grubworms and other insects which might seriously jeopardize the ultimate crop. Therefore the data obtained through the stomach examinations of birds by trained individuals should be the bases of determination in establishing the beneficial or harmful qualities of a species. Just because one or a few individuals, or even a flock of them for that matter, offend against man's welfare is no reason to assume that all members of a species everywhere are to be placed in the same disreputable category.

Extensive and reliable studies of the food of birds are available in government bulletins, bird books, and in numerous other publications. These should be consulted before opinions are fixed. Of the vast bird population in a state or county, very few are harmful. These few should be learned and their habits studied. In the East, the great-horned owl, duck hawk, Cooper's hawk, sharp-shinned hawk, starling, and English sparrow are the commonest of the objectionable species of birds.

It is a matter of common knowledge that many birds are omnivorous, eating both animal and vegetable matter, while others are insectivorous or carnivorous. The hawks, owls, and eagles devour living prey which may be other birds, snakes, frogs, or small mammals. They are particularly valuable in keeping down the number of destructive rodents. Even the sharp-shinned hawk and Cooper's hawk, which are considered the worst offenders in destroying chickens and beneficial birds, also destroy harmful rodents and snakes. On the whole, hawks are beneficial; and the common resentment against them is, for the most part, unjustified. The eagles, which occasionally take young sheep, have become too scarce in most sections to be an important factor. While all birds of prey may take species of birds and mammals which are decidedly beneficial, most of them compensate for this destruction by eradicating great numbers of harmful kinds. Greater thought should be given to the establishment of better protection for them. There is a widespread misconception of the valuable traits of these birds of prey, especially among sportsmen. Merriam estimated that the state of Pennsylvania suffered over two million dollars' damage from its famous "Scalp Act" which provided for the payment of bounties on a great number of hawks and owls.

The vultures and magpies chiefly feed upon carrion, and they

are valuable as scavengers. In some states the bluejay and the shrike or butcher bird are not protected because they are thought to destroy the nests, eggs, and young of other birds. The shrike undoubtedly kills smaller birds such as wrens, but it also feeds upon mice and insects. The bluejay is a permanent resident, and it may occasionally disturb other birds' nests; but in the winter

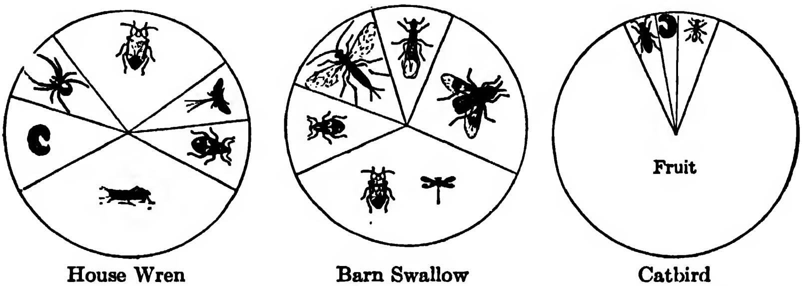


FIG. 201. Food of adult birds. After Judd, Bull. 17, courtesy U. S. Biol. Surv., U. S. Dept. Agric.

it could not subsist on the eggs and young of other birds. Its food, even in summer, consists mainly of fruits, seeds, and insects.

The seed-eaters such as the sparrows and finches render a valuable service in destroying the seeds of noxious weeds. Crows and blackbirds will frequently destroy corn which has been planted, and in such cases the offenders should be punished; but the wholesale destruction of any species is to be deplored. Crows sometimes take young chickens; and they undoubtedly destroy the nests of quail, grouse, and pheasants. They also eat small snakes and frogs.

The insect-eating birds are remarkable factors in reducing the damage done by insects. Catbirds, wrens, warblers, flycatchers, thrushes, vireos, larks, and a host of other insectivorous birds render a service to agriculture that cannot be estimated, and these birds are among the greatest and most valuable friends of man. Even the English sparrow, which is so generally despised because of its pugnacious habits, is a valuable ally because of its destruction of weed seeds, insects, and waste matters. Young sparrows are fed on a diet of soft-bodied insects such as measuring worms and other larvae until their beaks are hard enough to crack seeds. The worst feature of the English sparrow is its habit of keeping away other beneficial birds. All of the sparrows, finches,

and grosbeaks are chiefly vegetable feeders. The bobolink feeds upon seeds and insects in the North, but in the South it is sometimes called the rice bird. Traveling in tremendous flocks, the bobolink is said to do considerable damage to the rice crops of Louisiana.

Robins feed mainly upon insects and earthworms, but they also destroy many cherries and other small fruits. In fact they have become a problem in some sections, although they may manifest a preference for wormy fruits.

The kingfisher receives no protection in many sections because it is said to eat many fish which it kills with its spear-like bill. Other fish-eaters include the loons, gulls, terns, grebes, and ospreys. Herons and cranes also eat fish, but their diet consists mainly of frogs and crayfishes. The gulls, while chiefly scavengers, also devour living fishes.

In feeding there is a vast assortment of practices which are definitely related to the structural features of birds. The flight; the use of the feet and bill; and the places in which food is taken are all of interest in field observations. In the water, for instance, some birds like the ducks dive to the bottom for the stems and roots of aquatic plants. The loons and grebes dive and pursue fish under water. Swifts, swallows, whip-poor-wills, and nighthawks feed upon insects which they capture on the wing. The kingbird sits on a bough or a telegraph wire and darts after flying insects. Vireos hide in the recesses of the foliage waiting for passing insects which they pursue and which they bring back to the perch to eat. Cooper's hawk also waits on a perch for victims to make their appearance. Chickens, quail, and turkeys scratch in the dirt for insects and seeds, while swallows sometimes swoop down and pick up floating insects from the surface of the water. Chickadees, nuthatches, brown creepers, warblers, and titmice are gleaners or scratchers; and they find their food, which is entirely of insects, on the stems, under the leaves, and in the crevices of bark. Woodpeckers drill into the wood for larvae and adult insects; and humming birds have long, pointed bills for taking the nectar from flowers. Associated with all of these habits are the adaptive features mentioned above.

There are numerous sources of information about the food habits and economic importance of virtually every species of bird. While some of them may become destructive and at times menace

man's crops as well as the supply of game birds, mammals, and fish, the class of birds, as a whole, is a powerful and beautiful regulating unit allied with man in his efforts to find and produce sustenance. As a unit, it stands alone in its ability to invade every stratum of the environment in search of destructive pests.

Figure 201 shows the diet of three common birds.

Nests and Nesting Habits of Birds

The architecture of nests provides an interesting study which contributes to a well-rounded knowledge of birds. It also gives an insight into their engineering ability, as it evidences the attempts of these delightful creatures to provide for their offspring. The ingenious methods of attachment and construction of the nests and the cleverness with which they are concealed serve to increase respect for birds. Associated with the studies of nests and nesting habits are those pleasing observations of parental care so highly developed in birds.

The fact that each species has a more or less definite type of situation in which it nests has already been referred to. In the *Handbook of Birds of Eastern North America* Chapman tells where to find them. In the *Book of Bird Life* Allen gives a splendid key to the identification of nests. The descriptions of the nests of any local group would require many pages and without illustrations they would be inadequate for ready identification. The references at the end of the chapter will prove of value in identifying them.

The best time to study nests is in winter when they are easily seen and when they can be collected without injury to their builders. Of course the student will wish to see the birds build their nests; and during the nesting season he may even place desirable material such as string, cotton, dried grass, paper strips, and horse hair where the birds can be seen collecting it. He will also want to see the eggs and the young, but every precaution must be taken against injuring them or driving the parents away. When an occupied nest is studied, care should be taken not to pull down a branch and then let it go, for the eggs or young will be thrown out. If the branch is broken, it will be necessary for the parents to build another nest; and you may lose some desirable bird neighbors, for they will in all likelihood leave the immediate vicinity. While most species nest and lay their eggs in the spring

or early summer, some of them produce several broods in a season. The owls rear their young in winter, as a rule.

Eggs may be observed and their color and number recorded, but they should not be collected or handled. The young birds are often differently colored from their parents, and as in the robin and bluebird their color pattern shows their relationships. It is interesting to note that when the adult sexes are similarly colored, the young have a tendency to resemble their parents. Another interesting observation that should always be noted when studying nests and young is the condition of the young when they leave the egg. Many birds are born naked, and such species are raised in the nests. Such birds are called altricial, and the nests are usually complex in their construction because they are used for such a long time. Among the altricial species are robins, bluebirds, catbirds, sparrows, warblers, flycatchers, and, in fact, most of the tree-inhabiting birds as well as some ground nesters. The altricial species which do not make complex nests always find a well-protected cavity in which to rear their young. On the other hand, the young of pheasants, quail, grouse, ducks, snipe, plover, gulls, terns, turkeys, loons, and grebes leave the nest shortly after hatching and accompany their parents on foraging expeditions. Their bodies are pretty well covered with down and feathers when born. Such birds are precocial, and they make rudely constructed nests which are sometimes nothing more than a loose collection of sticks. The nests in precocial birds serve merely to hold the eggs, and they are not used for a long time as are the nests of altricial species. There is therefore no need for sturdy construction. The majority of precocial birds build their nests on the ground.

The concealment of nests depends upon the protection offered and upon the condition of the young at birth. While there is much to be learned about the use of the same nest by a species, it is well known that some species return to the same nest the following year. It is doubtful if the nest can be used for more than three seasons, and repair is always necessary the second season.

There are many agents which destroy the nests of birds—winds, rain, hail, other birds, squirrels, opossums, skunks, weasels, minks, cats, snakes, and human beings.

Birds use all sorts of material for their nests, which are placed

in a great variety of situations. Chimney swifts place their nests of woven twigs on the vertical surfaces of brick walls, securing the nests with a gluey substance which the parent birds vomit. The oriole uses mosses and plant fibers, and it hangs its nest from a drooping bough. It provides safety for the eggs and young by making the nest deep with a narrow opening at the top so that when the bough swings through an arc, the eggs or young cannot fall out. Humming birds use downy seeds and collect lichens from the barks of trees. The woodpeckers nest within the trunks of trees. The bank swallow and kingfisher nest in excavations, usually in clay banks. Wrens, bluebirds, nuthatches, crested flycatchers, chickadees, and others utilize small holes and cavities in trees, while owls select large cavities. Red-winged blackbirds attach their nests to standing reeds in marshes. Gulls and terns lay their eggs on sand in the center of a loose collection of sticks and pebbles. The grebe and marsh hawk build floating nests, made of the stems of reeds and rushes. Robins always have a middle layer of mud covered with dry grasses, as do wood thrushes and grackles. One of the principal objections to the sparrow is its untidy nest which is usually placed in most unfavorable locations for our comfort. But the list is too large for inclusion here. The student is referred to the books mentioned above and to the other references at the end of the chapter for full descriptions of nests and their locations.

In the study of nesting birds the student should find the answers to such questions as: Does the male select the nesting site? Where does each species normally build its nest? Do both birds construct the nest? How many eggs are laid? What are the colors of the eggs? Do both birds incubate the eggs? Do both sexes feed the young? When does the mating season begin? At what time are the eggs laid? When do they hatch? Is there more than one brood in a season? How long do the young remain with the parents? Are they naked or clothed at birth? When do the young first leave the nest?

Some types of birds' nests are shown in Fig. 200 on page 454.

The Migration of Birds

One of the most astonishing phenomena in the animal world is the migration of birds. In every community there occurs a rather spontaneous increase in the number of birds at certain seasons.

In the spring the birds arrive in countless numbers to take up a temporary residence with us, and soon the horde scatters over the countryside to build their nests. But after summer is over and fall winds foretell the coming of winter, they flock together with impatient actions; and suddenly they depart. To the average person this is the extent of knowledge of bird migration. The student of birds, however, is not content with such inadvertent observation and so meager a knowledge. He begins to wonder what it is all about and why it all happens. He asks such questions as: Why do birds migrate? What force or forces in nature prompt these feathered creatures to manifest such a wanderlust? Where do they come from, and where do they go? Of what biological significance is this migration? What factors are involved in such a mass movement?

Books have been written about bird migration, and to answer these questions in full would require more space than this book permits. The references at the end of the chapter will prove of value to the interested student. Then, too, some of these questions cannot be answered, for there is much to be learned about the migration of birds. Certainly the birds are better adapted to migrating than any other animal group, and a wide dissemination of species is to be expected; but when the known facts of bird travel are considered, the factors involved are numerous and at times enigmatical.

There is no question that food is a determining factor in migration. The insectivorous birds, with the exception of those capable of feeding on insect eggs, pupae, and on adult insects hibernating in the crevices of bark, must move southward when insect activity ceases in the fall. The seed-crackers and scratchers are frequently able to find sufficient food in winter, and many of them remain.

But the remarkable features of the southward migrations are that those which migrate do not usually stop when they arrive at suitable feeding grounds. Many of those species go thousands of miles more than is necessary to find food. Furthermore, some of the migrating species leave behind them some close relatives which find sustenance during the winter months. Then, too, the snow bunting, tree sparrow, redpoll, and kinglet, which nest in the Northland, close to the arctic circle, come down to the northern states to spend the winter with the chickadee, nuthatch, downy

and hairy woodpeckers, and the other winter residents of our woodlands.

The bobolink, veery, golden plover, warblers, vireos, some fly-catchers, swallows, black poll warbler, and many others travel to different parts of South America. The arctic tern, which nests in the Far North, migrates to the Antarctic, a distance of 11,000 miles, to spend the winter. It is said that this bird sees more hours of daylight than any other bird in the world. The long arctic night is the probable impetus for migrating, and its trip to the Antarctic requires about ten weeks. Its daily average would be approximately 150 miles per day. The golden plover is reputed to make the longest non-stop flight. Its normal haunts are along the arctic coast of North America, where the breeding season is short. Shortly after hatching, the young migrate to the coast of Labrador and then move on to Nova Scotia. From here they begin an oceanic voyage of 2400 miles to the northeast coast of South America, later crossing the equator which is the end of their journey. The return route is frequently a more nearly direct one.

The wood thrush winters in Central America, while the robin and bluebird remain in our southern states. Northerners who winter in Florida must be astounded by the huge flocks of robins which inhabit the Everglades or which sometimes descend upon the towns in units numbering thousands.

It seems as though some impelling instinct is the causative stimulus for these extensive journeys, and a study of the history of birds indicates that this is so.

When the North country was covered with snow and ice, the frigid temperatures precluded plant and insect activity on a large scale. In those days the bird life was confined to the southern hemisphere where food was obtainable. As the glaciers receded and the land once more became habitable, the birds progressed northward; and it may be that extensive migrations are the result of an instinctive call to ancestral homes. That this is a possible factor is further indicated by the fact that some northern summer residents migrate across the Atlantic where they join their European relatives for the southward journey.

Migration usually takes place at night, and the honking of geese in the middle of the night is not uncommon in the migration periods. On moonlight nights thousands of migrating birds can

occasionally be seen as they pass between an observer and the moon, their dark bodies silhouetted against the lunar light. At daybreak they descend to feed and rest and then take off again when night settles. There are some birds which migrate by day, such as robins and swallows; and quite a number travel both by day and by night.

There are many dangers attendant to migration. Tall buildings and smoke stacks are frequently responsible for the deaths of thousands of migrating birds which fly against them in the darkness. The lights of lighthouses confuse many of the travelers and cause them to batter themselves to death against the glass. High winds sweep numbers of birds out to sea, and on one occasion the writer while traveling on a freighter to an obscure port in South America counted over 300 birds which had settled on the ship some 200 miles off the Venezuelan coast. Most of them were so exhausted when they alighted that it was not possible for them to fly again for many hours. These were only a fraction of vast hordes which very likely did not find a resting place. Storms frequently beat down the migrants, and they are responsible for thousands of casualties.

In migrating there are definite routes which are followed as a rule, although when food is scarce the birds may take an entirely different one. While most species follow highways, such as mountain-chains, river valleys, and land connections between continents, there are certain species which travel over vast expanses of water in taking the shortest route. Plate XX shows some of the routes of migration between North and South America.

Most of the data about bird migration have been obtained through banding. Aluminum bands, with locality and date records on them, are placed on species which are trapped and later released. Bird-banding societies and investigating scientists are continually studying the extent of migration, and correspondents all over the world coöperate in the collection of data. The American bird-banding associations are making valuable contributions to the ever-increasing knowledge of bird travel.

The marvels of bird migration are many; and who would not like to know the answer to such questions as: How do they assemble in thousands for journeys *en masse?* What instincts guide them in their long and perilous flights? How can they find their

ways back to the nesting sites of previous years? What are the signs by which they know just when to start north and south?

Certainly their perseverance and energy are splendid virtues which we humans would do well to emulate.

The bird calendar. The values of a bird calendar have already been suggested, and every class in bird study should keep one. It serves to stimulate active interest in observations; and when properly made, it is the basis for determining local species, their habitat selections, the dates of arrival and departure, visitants, etc.

On the calendar the name of the bird, where and when it was first seen, and the observer's name should be listed. When possible, the activities such as swimming, wading, scratching, flying, soaring, feeding, etc., should be listed. School calendars may be made on large sheets of white wrapping paper or on cardboard; and they can be made attractive by placing a colored picture of the species with the observation record. Individual records for each bird can be kept on separate cards, if desired. The calendar should be a class project.

The data on the calendar can be listed in the following manner: [1]

NAME OF BIRD (*preferably with colored picture*)	LOCALITY	HABITAT	ACTIVITIES	DATE	OBSERVER

BIBLIOGRAPHY

Birds

Allen, A. A., *Book of Bird Life.* Van Nostrand, 1920.

Allen, G. M., *Birds and Their Attributes.* Marshall and Jones Co., 1925.

Apgar, A. C., *Birds of the United States East of the Rocky Mountains.* American Book Co., 1898.

Ashbrook, F. G., *The Blue Book of Birds of America.* Whitman Publishing Co., 1931.

——, *The Green Book of Birds of America.* Whitman Publishing Co., 1931.

——, *The Red Book of Birds of America.* Whitman Publishing Co., 1931.

[1] See Allen, A. A., *Book of Bird Life*, pp. 325, 327.

Baldwin, S. P., and others, *Measurements of Birds.* Cleveland Mus. of Nat. Hist. Sci. Pub., Vol. 2, 1931.

——, "The Protection of Hawks and Owls in Ohio," *Ohio Jour. Sci.*, Vol. XXXII, No. 5, 1932.

Barrows, W. B., *Michigan Bird Life.* Bull. Mich. Agriculture, 1912.

Baynes, E. Harold, *Wild Bird Guests.* Dutton, 1915.

Beal, F. E. L., *Food of the Bobolink, Blackbirds, and Grackles.* Bull. 13, Biol. Sur. U. S. Dept. Agric., 1900.

——, *Food of Our More Important Flycatchers.* Bull. 44, Biol. Sur. U. S. Dept. Agric., 1912.

——, *Food Habits of the Thrushes of the United States.* U. S. Dept. Agric. Bull. No. 280, 1915.

Beebe, C. W., *The Bird, Its Form and Function.* Henry Holt, 1906.

Bennitt, Rudolf, *Check List of Birds of Missouri.* Missouri Univ. Studies, Vol. 7, No. 3, 1932.

Bent, A. C., *North American Diving Birds.* U. S. Nat. Mus., Bull. 107 (1919).

——, *Life Histories of North American Marsh Birds.* U. S. Nat. Mus., Bulls. 135 (1926), 107 (1919), 126 (1923), 113 (1921), 121 (1922), 130 (1925).

——, *Life Histories of North American Shore Birds.* U. S. Nat. Mus., Bulls. 142, 146 (1927 to 1929).

Black, J. G., *Bird Nesting.* Reid, 1929.

Blanchan, Neltje, *How to Attract Birds.* Doubleday Page, 1902.

——, *Bird Neighbors.* Doubleday Page, 1922.

——, *The Bird Book.* Doubleday Doran, 1932.

Boulton, Rudgerd, *Traveling with the Birds.* Donohue, 1933.

Bready, Mrs. M. B., *The European Starling on His Westward Way (Sturnus vulgaris vulgaris).* Knickerbocker Press, 1929.

Butler, A. W., *Birds of Indiana.* Ind. Geol. and Nat. Res. Rep., Vol. 20, 1897.

Chapman, F. M., *Color Key to North American Birds.* Doubleday Page, 1903.

——, "Birds' Nests and Eggs," *Amer. Mus. Jour.*, Vol. IV, No. 2, Guide Leaflet No. 14, 1904.

——, *The Warblers of North America.* Appleton, 1907.

——, *Bird Life.* Appleton, 1914.

——, *The Travels of the Birds.* Appleton, 1916.

——, *Our Winter Birds.* Appleton, 1918.

——, *What Bird Is That?* Appleton, 1920.

——, *Handbook of Birds of Eastern North America.* Appleton, 1932.

——, *Autobiography of a Bird-Lover.* Appleton, 1933.

Clark, A. H., *Animals of Land and Sea.* Van Nostrand, 1927.

Coble, M. F., *Introduction to Ornithological Nomenclature.* Straube Printing Co., 1932.

Comstock, A. B., *Handbook of Nature Study.* Comstock Pub. Co., 1911.

Cooke, W. W., "Our Greatest Travellers," *Nat. Geog. Mag.*, Vol. XXII, 1911, pp. 346–365.

Coues, E. A., *Key to North American Birds.* Dana Estes and Co., Boston, 1884.

Coursen, C. B., *An Outline of Bird Study.* General Biol. Supply House, 1928.

Dearborn, Ned, *Bird Houses and How to Build Them.* Farmers' Bull. 609, U. S. Dept. Agric., 1922.

Delamain, J., *Why Birds Sing.* Coward-McCann, 1931.

Dodson, J. H., *Your Bird Friends and How to Win Them.* Schlau, Burnett and Co., 1928.

Du Mont, P., *A Revised List of the Birds of Iowa* (University of Iowa Studies), Vol. XV, No. 5, 1933.

Eaton, E. H., *The Birds of New York.* Mem. N. Y. State Mus. 12, Part I, 1909.

——, *The Birds of New York.* Mem. N. Y. State Mus., Part II, 1914.

Finley, W. L., *American Birds.* Scribner, 1907.

Fisher, G. C., *Nature's Secrets*, 2 vols. Univ. Soc., 1933.

Forbush, E. H., *Useful Birds, Their Protection.* Mass. Board of Agric., 1907.

——, *Birds of Massachusetts and Other New England States.* Mass. Dept. Agric., Vols. 1, 2, 3 (1925 to 1929).

Friedmann, H., *The Cowbirds; a Study in the Biology of Social Parasitism.* Thomas, 1929.

Headley, F. W., *The Flight of Birds.* Witherby and Co. (Scribner, U. S. agents), 1912.

Heaps, W., *Emigration, Migration, and Nomadism.* W. Heffer and Sons, 1931.

Heilman, G., *The Origin of Birds.* Appleton, 1927.

Henderson, J., *The Practical Value of Birds.* Macmillan, 1927.

Herrick, F. H., *The Home Life of Wild Birds.* Putnam, 1902.

Hornaday, T. W., *The Destruction of Our Birds and Mammals.* 2d Ann. Rep. of N. Y. Zoöl. Soc., 1901.

Howard, H. E., *Territory in Bird Life.* John Murray, 1920.

Howell, A. H., *Birds of Alabama.* Dept. Game and Fisheries, Montgomery, Ala., 1924.

——, *Florida Bird Life.* Fla. Dept. Game and Fresh Water Fish, in coöp. with Bur. Biol. Sur., U. S. Dept. Agric., 1932.

Job, H. K., *Among the Waterfowl.* Doubleday Page, 1903.

——, *How to Study Birds.* Outing Co., 1910.

Job, H. K., *Wild Wings*. Houghton Mifflin, 1925.
Judd, S. D., *Birds of a Maryland Farm*. U. S. Dept. Agric., Bull. 17, Div. Biol. Survey, 1902.
Kalmbach, E. R., *The Crow in Its Relation to Agriculture*. U. S. Dept. Agric., Farmers' Bull. 1102 (1920).
Kendeigh, S. C., *The Rôle of Environment in the Life of Birds*. Ecological Monographs 4, 1934, pp. 299–417.
Lewis, John B., "Sight and Scent in the Turkey Vulture," *The Auk*, Vol. 45, 1928, pp. 467–470.
Louisiana Conservation Dept., *Birds of Louisiana*. 1931.
Matthews, F. S., *Fieldbook of Wild Birds and Their Music*. Putnam, 1904.
McAtee, W. L., *How to Attract Birds*. U. S. Dept. Agric. Farmers' Bulls. 621 (1914), 760 (1918), 844 (1917), 912 (1918).
——, *The Relation of Birds to the Woodlots in New York State*. Roosevelt Wild Life Bull., Vol. IV, No. 1, 1926.
——, "A Little Lesson on Vermin," *Bird-Lore*, Nov.-Dec., 1931.
——, *Homes for Birds*. U. S. Dept. Agric., Farmers' Bull. 1456 (1924).
——, *Effectiveness in Nature of the So-called Protective Adaptations in the Animal Kingdom*. Smithson. Inst. Misc. Coll., Vol. 85, 1932, No. 7.
Merriam, F. A., *Handbook of Birds of Western United States*. Houghton Mifflin, 1927.
Michelet, J., *The Bird*. Nelson, 1876.
Mills, E. A., *Bird Memories of the Rockies*. Houghton Mifflin, 1931.
Morse, S. R., *The Birds of New Jersey*. Rept. N. J. State Mus., 1903.
National Geographic Society, *The Book of Birds*. 1927.
Neff, J. A., *A Study of the Economic Status of the Common Woodpeckers in Relation to Oregon Horticulture*. Free Press Print, 1928.
Nicholoson, E. M., *The Study of Birds*. Benn, 1929.
——, *The Art of Bird-Watching*. Witherby and Co., 1931.
Pearson, T. G., *The Bird Study Books*. Doubleday Page, 1923.
Pellett, F. C., *Birds of the Wild; How to Make Your Home Their Home*. De La Mare, 1928.
Peterson, R. T., *A Field Guide to the Birds*. Houghton Mifflin, 1934.
Phillips, J. C., *American Waterfowl*. Houghton Mifflin, 1930.
——, *American Game Mammals and Birds*. Houghton Mifflin, 1930.
——, *Wild Birds Introduced or Transplanted in North America*. U. S. Dept. Agric. Tech. Bull. 61, 1931.
——, *Migratory Bird Protection in North America*. John C. Phillips, 1934.
Phillips, J. C., and Lincoln, F. C., *American Waterfowl*. Houghton Mifflin, 1930.
Reed, C. A., *North American Birds' Eggs*. Doubleday Page, 1904.
——, *Land Birds*. C. K. Reed, 1910.
——, *Water Birds*. C. K. Reed, 1910.

Reed, C. A., *Birds of Eastern North America.* Doubleday Page, 1912.

Ridgway, Robert, *A Nomenclature of Colors for Naturalists, and Compendium of Useful Knowledge for Ornithologists.* Little, 1886.

——, *The Birds of North and Middle America.* Parts I to VIII, U. S. Nat. Mus., 1901 to 1919.

Roberts, T. S., *The Birds of Minnesota.* 2 vols. Univ. Minn. Press, 1932.

Roosevelt, Theodore, "Unpublished Letters. On the Revealing and Concealing Coloration of Birds," *Condor*, Vol. XXVI, 1924, pp. 94–98.

Roosevelt, T., and Minot, H. D., *The Summer Birds of the Adirondacks in Franklin County, New York.* Privately printed, 1925.

Rowan, W., *The Riddle of Migration.* Williams, 1931.

Saunders, A. A., *Birds of Central New York Marshes.* Roosevelt Wild Life Bull., Vol. III, No. 3, 1926.

——, *Bird Song.* N. Y. State Mus. Handbook 7, 1929.

——, *Notes on the Summer Birds of Allegany State Park.* Roosevelt Wild Life Bull., Vol. III, No. 3, 1926.

Schantz, O. M., *Birds of Illinois.* Ill. Dept. of Conservation, Pub. No. 6, 1928.

Sheahan, H. B., *The Outermost House; a Year of Life on the Great Beach of Cape Cod.* Doubleday Doran, 1929.

Shoffner, C. P., *The Bird Book.* Manson, 1929.

Spiker, C. J., *A Biological Reconnaissance of the Peterboro Swamp and the Labrador Pond Areas.* Roosevelt Wild Life Bull., Vol. 6, No. 1, 1931.

Stoddard, H. L., *The Bobwhite Quail; Its Habits, Preservation, and Increase.* Scribner, 1931.

Street, J. F., *Brief Bird Biographies.* Grosset, 1933.

Sutton, G. M., *An Introduction to the Birds of Pennsylvania.* J. H. MacFarland Co., Harrisburg, 1928.

Thomson, J. A., *The Biology of Birds.* Sedgwick and Jackson, London, 1923.

Todd, W. E. C., *The Birds of Western Pennsylvania* (in press), 1936.

Trafton, G. H., *Methods of Attracting Birds.* Houghton Mifflin, 1910.

Warren, B. H., *The Birds of Pennsylvania.* Report of Pa. State Bd. of Agric., 1890.

Wetmore, Alexander, *The Migration of Birds.* Harvard Univ. Press, 1926.

——, *A Systematic Classification for the Birds of the World.* U. S. Nat. Mus. Proc., Vol. 76, Art. 24, 1930.

Weygandt, C., *The Wissahickon Hills; Memories of Leisure Hours Out of Doors in an Old Countryside.* Univ. Pennsylvania Press, 1930.

Wilson, Alexander, *Wilson's American Ornithology*, with Notes by Jardine. Magagnos, 1854.

Wright, M. O., *Birdcraft.* Macmillan, 1895.

Wycraft, W. P., *A History of Birds.* Methuen Co., 1910.

CHAPTER XIX

THE STUDY OF MAMMALS

Next to birds, the mammals are the most conspicuous of the vertebrate animals. Among them are found the giants of the animal world. The mammals range in size from a tiny shrew in Maryland and Virginia (*Microsorex hoyi*), which measures less than three inches, to the giant sulphur bottom whale which has been known to attain a length of 103 feet. Tiny mice and huge African elephants are the more commonly known dwarfs and giants among the mammals, however.

As a group, the mammals because of their size and abundance present a readily accessible contingent for study. Every section of the United States has a number of mammalian representatives such as rabbits, rats, mice, gophers, or squirrels. Even domesticated animals such as dogs, cats, rabbits, horses, cattle, sheep, and goats provide excellent opportunities for anatomical and ecological studies. In fact the house cat and the family dog should be studied first, for they illustrate many of the mammalian principles mentioned here. The mammals exhibit a wide adaptive radiation and every type of environment has been invaded by them. Consequently they present a varied assortment of modified structures. They also provide numerous opportunities for the observation of biological principles such as defense, secondary sexual characters, parental care, family relationships, home building, rearing of young, coöperation, predatism, adaptive color patterns, habitat selection, protective coverings, hibernation, dentition, and geographical distribution.

The general characters of mammals. The mammals belong to the division of the animal kingdom known as Vertebrates. These are distinguished from other animals by the fact that they possess an internal skeleton which is supported by a vertebral column or backbone. The group includes the fishes, amphibians, reptiles, birds, and mammals. However, the mammals differ from the others in two important respects. In the first place, the mammals are the only animals that possess an external coating of hair;

secondly, the young of mammals are nourished by secretions extracted from the bodies of their mothers through the mammary or milk glands which lead to the exterior through the breasts or nipples located on the ventral side of the body.

All mammals are warm blooded (homoiothermal) and therefore they maintain a constant temperature. This body temperature is produced in several ways. The chemical changes involved in the metabolism of foodstuffs produce heat which is distributed through-

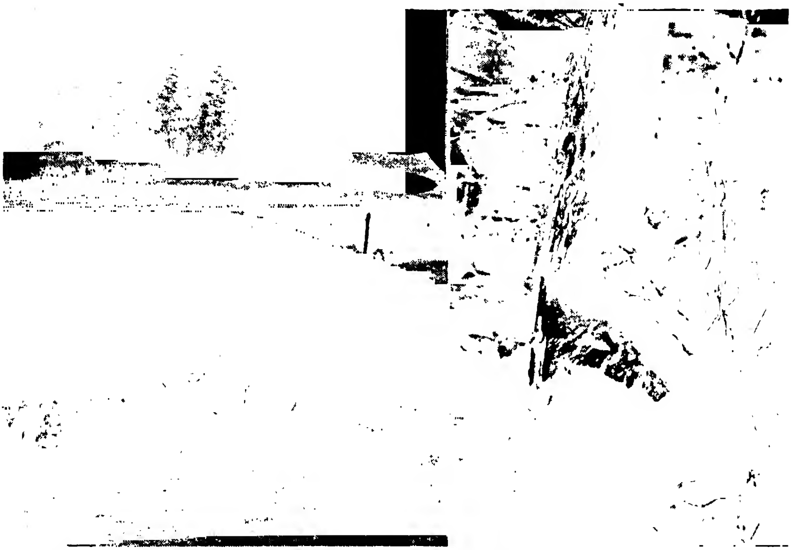


Fig. 202. The beaver, its home and work. Animal, original photograph; home and damage, Biol. Surv., U. S. Dept. Agric.

out the body by the closed circulatory system. This is the chief source of heat in homoiothermal animals. The heat is retained by the external hair coat which prevents the rapid radiation of the body heat. The density of the hair coat is regulated by climatic changes.

With only a few exceptions, the mammals are all viviparous; that is, they bring forth living young which have all of their organs and systems developed at birth. The Australian duck-billed "mole" (*Platypus*) and the spiny anteater (*Echidna*) are primitive mammals which lay eggs as do birds and most reptiles. When the eggs hatch, the young are nourished by their mothers in the usual way. However, in these primitive mammals, the external

mammae or breasts, which are highly specialized structures, are not developed. The milky secretions exude through pores on the ventral side of the body and are licked off by the young. Morphologically, the mammary glands of all mammals are modified sweat glands.

The viviparous habits, which are most highly developed in mammals, are not characteristic of mammals alone, however; and many other animals, including certain snakes, lizards, fishes, and even some insects, bring forth their young alive. The young of mammals undergo a long period of gestation during which they are attached to the mother by a placenta, and they receive their nourishment during development from the blood stream of their parent through the umbilical cord. The mammals are the only viviparous animals which have a placenta. The place of attachment of the umbilicus to the fetus, as the developing young is called, is revealed by the navel. While this internal development is a primary characteristic of mammals, there are some mammals which lack the placenta and the cord. The marsupials, which include the opossums and kangaroos, do not develop much beyond the embryo within the body of the mother, and they lack the placental attachment. The young marsupial is born in a very immature state and completes its development within the marsupium or pouch where it is nourished through the mammae to which it immediately attaches itself.

All mammals are air breathing and although certain kinds, such as whales, manatees, and porpoises live in the water, they must all come to the surface for air.

The hair of mammals. It has already been stated that the hair coat is a distinctive and exclusive feature of mammals. The permanently aquatic mammals such as whales and dolphins have lost their external hair coats in response to environmental demand. The vibrissae on the face and a few scattered body hairs are all that remain of a general hairy covering in these mammals. In place of the hair coat, which is primarily a temperature regulator in land mammals, the aquatic mammals have developed beneath the skin a layer of fatty tissue called blubber, which serves as an insulator and guards them against sudden temperature changes. In these aquatic forms the sweat glands also have disappeared, since there is no need for them.

In those mammals such as otters, beavers, seals, minks, and

muskrats, which are not permanently aquatic but which spend a considerable amount of time in the water, the hair is short so as not to seriously impede their progress in the water, and it is compact to keep the skin dry.

The primary purpose of a hair coat is protection. This is effected in two ways: (1) it provides insulation against sudden changes in the temperature of the surrounding medium; and (2) it affords protection from serious injury by the teeth of other animals. A long-haired animal is much less likely to receive lacerations of the flesh than a short-haired one. The hair also sheds water and keeps the skin from the chilling effects of rain and fog. The long-haired giant anteater of South America has a wide, hairy tail which covers the curled body of the animal while it sleeps.

Some mammals are born with a fine silken coat of hair, while others are born naked. The hairless young are usually kept warm by contact with the body of the mother or by being cuddled together in a well-lined nest. It is significant that the young of mammals which build cozy nests are usually naked when born (mice, opossums, etc.), while those of mammals which either do not make any nests at all or which construct only crude shelters (deer, monkeys, pigs, cats, foxes) are covered with hair at birth, as a rule.

There are three kinds of hair on a mammal: (1) the long, coarse overhair, which is protective; (2) the fine, soft under fur which serves to preserve the normal body temperature; and (3) highly specialized hairs or vibrissae which are sensory. The "whiskers" located on the face and which are especially conspicuous in the cats, and the coarse hairs often found above the eyes and on the wrist near the hand, are vibrissae. They are evidently sensory and aid the senses of smell, touch, and hearing. There are many changes that take place in the growth of mammalian hair, and there are considerable differences among the types of hair of infancy, youth, and maturity. The adult hair is usually much coarser.

The distribution of hair over the surface of the body is also variable according to species and localities, but it is generally longer and denser on the dorsal surface. On virtually all forms there are areas which are almost or entirely devoid of hair. These areas are the snout, under the hind legs, and around the mammae.

The length and density of the hair are regulated by seasons. Mammals are known to have heavier coats in winter than in sum-

mer, and trappers always secure skins for commercial purposes during the winter months. In the spring there is a shedding or molt of surplus hair. In some species there is also another molt very early in the fall. Then the winter coat begins to develop; and by the time the first snowfall arrives, the creatures are prepared to withstand wintry blasts. The shaggy coats of horses and cattle in the winter are familiar to everyone, and they are characteristic of nature's method of supplying additional warmth to animals that cannot live in warm-lined nests or which cannot cover themselves as humans do.

The hair is frequently modified for specialized protection; and in the porcupine some of it has developed into loose, sharp, barbed quills. The shell of the armadillo is homologous to the normal hair coat of other mammals.

The teeth of mammals. The teeth are among the most important features in the determination of mammalian identities. Because of their adaptability to preservation, they have been the bases of determining the character of numerous animals now extinct and whose incomplete and disintegrated fossil remains are the only remnants of a prehistoric fauna. Furthermore, the teeth exhibit a variety of size, form, and number according to the manner in which they are used; and they reveal some very interesting adaptive modifications. Inasmuch as mammals are usually somewhat limited in their diets, their dentitions are so remarkable in character that they serve as a basis for differentiating among the various mammalian groups. Even the food habits of individuals can be determined by observing the highly specialized character of their teeth. Some mammals feed entirely upon plants, while others limit their food to the flesh of other animals. Some species are indiscriminate in their feeding habits, and they devour both plant and animal structures and products. Consequently there exists a wide variation in the sizes, numbers, forms, and distribution or arrangement of the tooth formations in mammalian groups.

The primary functions of teeth are to seize, tear apart, and masticate food. In many kinds of animals they also serve as excellent weapons of defense and offense. The animals which feed upon plants are said to be herbivorous. Those which live upon flesh are called carnivorous animals. Those which eat both plants and animals are known as omnivorous animals. There are some insectivorous mammals which feed entirely upon insects. The fox,

otter, mink, weasel, and cat are carnivorous. Bats, shrews, and moles are insectivorous. Deer, cattle, horses, woodchucks, and rabbits are herbivorous.

The carnivorous mammals have teeth adapted to tearing flesh and crushing bones (Fig. 204). The herbivorous mammals have

FIG. 203. Home of the muskrat. From. Biol. Surv., U. S. Dept. Agric.

teeth fitted for cropping plants and for triturating vegetable tissues (Fig. 207), while the insectivorous mammals have numerous teeth with many sharp-pointed cusps for crushing the chitinous bodies of insects. Some insectivorous mammals such as anteaters have no teeth at all. The omnivorous mammals have a combination of the features of the carnivorous and the herbivorous teeth.

As a rule the number of teeth in a species is more or less fixed and constant, and the dental formula of a species is usually given with its description.

There are four distinct types of teeth in mammals: (1) The incisors or front teeth which are sharp and more or less elongated, according to the species. They are used chiefly for gnawing or biting. The incisors are the most highly developed and conspicuous

teeth in the rodents, which are known as gnawers. (2) The canines or eye teeth are the ones next to the incisors on the sides. They are flesh-tearing teeth, and they are the prominent teeth in carnivorous mammals such as bears and wolves. Sometimes they are developed into razor-like tusks and are formidable weapons of defense. (3) The premolars are the anterior grinding teeth. They are located just back of the canines and are called the bicuspids in man. (4) The molars are the posterior grinding teeth which are somewhat

FIG. 204. The skull of a black bear showing carnivorous dentition. From Williams, *The Mammals of Pennsylvania.*

flattened with rough upper surfaces. On these most vegetable chewing takes place. In the edentates and cetaceans the teeth are all alike, and the animals are said to be homodentitious. When different kinds of teeth are present, the animals are heterodentitious.

As a rule, mammals have two sets of teeth in a lifetime, although this is not always the case. The first teeth, called the milk teeth, are only temporary; and they differ in some respects from the adult series. In humans the posterior molars are not present in the milk or baby teeth. In man there is the same number of teeth of each kind in both the upper and lower jaws. This does not hold for all other mammals. In dolphins the teeth are variable in number due to the extension of the beak. The number on one side of the jaw may be different from that on the other side, and ofttimes some teeth are out of line while others are embedded in the gums. The lack of fixity in the dental formula indicates the transitional character of these animals. In the sheep, for instance, which is a grazing mammal, there are no incisors or canines in the upper

jaw; but it has three incisors and two canines in the lower jaw. The structure of teeth varies also in mammals, although the enamel, dentine, and pulp are the characteristic constituents above the gums.

The teeth of horses and cattle continue to grow for a considerable length of time after the animals have attained maturity, and they

FIG. 205. Skulls of rabbit (left), mink (center), and woodchuck (right). From Williams, *The Mammals of Pennsylvania.*

do not form roots until late in life. This is because they feed upon abrasive substances such as the woody material of plants, and the growth compensates for the wear on them. The relative age of a horse can be determined by looking at its teeth. If they are long and if the upper surfaces are worn considerably, the horse is well along in years.

The chisel-like incisors of the gnawing animals such as beavers, rats, and woodchucks (Fig. 205) grow during the entire life of the

FIG. 206. Skulls of fox (left) and otter (right). From Williams, *The Mammals of Pennsylvania.*

mammals; and they are kept at a fairly constant length by use. If a rodent loses one of its incisors, the opposing tooth continues to grow in length until it eventually prevents feeding by locking the jaws. The hard enamel is present only on the face of the incisors in the gnawing mammals; and as the animals feed, the softer portion

(dentine) wears away much more rapidly, thus maintaining a sharp, beveled, cutting edge. This is particularly noticeable in beavers.

The skeleton of mammals. The diversity of form in mammals implies a variation in the internal supporting skeletal structures. Although striking differences in the form and size of skeletal parts may be seen within the mammals, a comparative study of the corresponding parts shows that the skeletons of mammals in general are remarkably similar in character. In fact they are bone for bone almost identical. The different shapes of mammals are due to the fact that certain bones may be larger or smaller and of different form than the corresponding bones in other species.

The mammalian skeleton (Fig. 208) is composed of two main portions—the axial and the appendicular. The former includes the skull, backbone or vertebral column, ribs, and breastbone or sternum. The appendicular portion comprises the limb bones and the bones attaching them to the trunk.

The skull is a highly complex structure composed of many parts, most of which are immovably joined together. It is the seat of the principal sense organs such as the eyes, ears, nose, and mouth. It also affords a well-protected cavity for the brain, in addition to carrying the teeth. The lower jaw is movable, and this enables the animals to bite off and masticate food. The section of the skull which carries the brain, eyes, and ears is called the cranium. The section in front is called the face. The rear of the skull is called the occiput.

The vertebral column is made up of a number of separate bones called vertebrae. They are articulated together in such a way as to permit flexibility and at the same time impart a rigidity which gives the necessary strength to the spinal column. The function of the spinal column or backbone is twofold: (1) to support the main part of the body and to afford attachment for the limbs and tail; and (2) to support and protect the spinal cord which is the central axis of the nervous system. While the vertebrae differ greatly in form and appearance, particularly in the region of the neck, they are, nevertheless, constructed on the same general plan.

The body of each vertebra is called the centrum, and the centra are separated by discs of cartilage or gristle which allow elasticity. On the upper surface of the centrum is an arch, called the neural arch, which encloses the neural canal. Through the neural canal runs the spinal cord. There are five general regions of the backbone.

They are: (1) The cervical region or neck in which there are usually seven vertebrae. Long-necked animals like the giraffe have no more cervical vertebrae than short-necked ones like the woodchuck. The difference is in the length of the vertebrae. (2) The thoracic region which includes the vertebrae to which the ribs are attached. (3) The lumbar region, included in which are the ver-

FIG. 207. The skull of a Virginia deer. From Williams, *The Mammals of Pennsylvania.*

tebrae from the thoracic region to the (4) sacrum which includes a variable number (2 to 13) of fused vertebrae which appear as a solid structure and to which the hind limbs are attached. (5) The caudal region including the vertebrae of the tail.

The appendicular skeleton consists of the limb girdles and the bones of the limbs and feet. The limb girdles are the means of attaching the limbs to the body in such a way as to allow mobility. The shoulder or pectoral girdle has no direct articulation with the vertebral column and is held in place by muscles. It is made up of the shoulder blade or scapula and the collar bone or clavicle, although not all mammals possess the latter.

The posterior girdle is called the pelvic girdle, and it is attached to the sacral vertebrae. It affords a solid support for the hind legs. The pelvis is composed of three parts; viz., the ilium, ischium, and

pubis which are separated in young animals but fused together in old ones. These three parts are united in a deep hemispherical pit called the acetabulum, which receives the head of the thigh bone in a ball and socket manner.

The limbs are composed of three segments. In the fore limbs they are: upper arm, fore-arm, and hand. In the hind limbs they

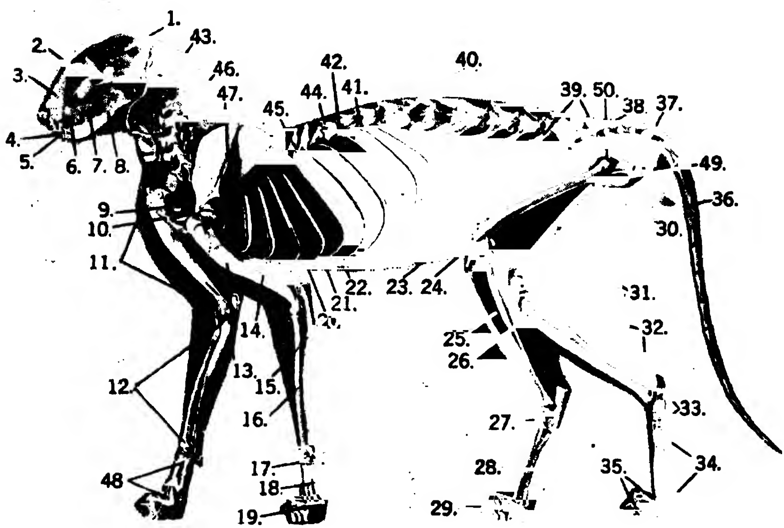


FIG. 208. The skeleton of a typical mammal (the cat). 1. Cranium; 2. Eye socket; 3. Face; 4. Incisor; 5. Canine; 6. Premolar; 7. Molar; 8. Mandible; 9. Clavicle; 10. Manubrium; 11. Fore-arm; 12. Arm; 13. Humerus; 14. Sternum; 15. Ulna; 16. Radius; 17. Carpus; 18. Metacarpus; 19. Phalanges; 20. Rib; 21. Costal cartilage; 22. Xyphoid process; 23. Patella; 24. Femur; 25. Tibia; 26. Fibula; 27. Tarsals; 28. Metatarsals; 29. Phalanges; 30. Ischium; 31. Thigh; 32. Leg; 33. Ankle bone; 34. Foot; 35. Toes; 36. Caudal vertebrae; 37. Pubis; 38. Ilium; 39. Sacrum; 40. Lumbar vertebrae; 41. Intervertebral disc; 42. Centrum; 43. Hyoid; 44. Spine; 45. Articulation for rib; 46. Cervical vertebrae; 47. Scapula; 48. Palm; 49. Obturator foramen; 50. Acetabulum.

are: the thigh, leg or shank, and the foot. The upper bone in the arm is the humerus, and those of the fore-arm are the radius and ulna. The fore foot or hand is also composed of three parts corresponding to the wrist, palm or back of palm, and the fingers. The bones of the wrist constitute the carpus; those of the palm and back, the metacarpus; and those of the fingers or toes. the pha-

langes. The bones in the hind limb are similar to those in the front or fore limb. The upper or thigh bone is the largest and is called the femur. The bones of the lower limb are the tibia or shin bone (inner) and the fibula (outer). The fibula is not well developed in horses and ruminants, and it exists in these as a splint fused to the tibia. The foot bones of the hind limb are similar to those of the fore foot or hand; and the three parts are called the tarsus, metatarsus, and phalanges. The upper bones of the tarsus are peculiarly modified to form the ankle joint and the heel.

An animal may walk with the entire sole of its foot in contact with the ground as do bears, raccoons, and humans. Such an animal is called plantigrade or flatfooted. When it walks on its toes as do cats, dogs, and foxes, it is digitigrade. The tracks of some of our native mammals are shown in Plate XXIV.

Where mammals live. The mammals present a very interesting assortment of preferences in choosing places in which to live and build their homes. Some of them have specially adapted structures which determine the habitats in which they are to be found. Because of the diversity of situations in which they live, the mammals may be classified as *aerial, aquatic, terrestrial, subterranean,* and *arboreal.*

The aerial forms include the bats and flying squirrels. The flight of the flying squirrels is purely passive, however, and must not be confused with the active flight of bats. The aerial movements of the flying squirrel may be considered as volplaning or gliding. Flying squirrels are confined to forests, while bats are most frequently seen in flight. Since both are nocturnal, they are seldom seen by the average person.

The mammals are not, as a rule, great builders. The beaver, muskrat, deer mouse, and some squirrels construct complex homes; but most mammals resort to cavities: trees, and caves, and to natural excavations for establishing their domiciles although a number of species burrow in the ground. On the whole, the mammals seem to lack the ingenuity to make, for themselves, houses that are comparable in complexity to those of the birds.

The aquatic mammals include the whales, dolphins, manatees, beavers, muskrats, otters, seals, polar bears, walruses, minks, fishers, and other species which are exotic such as hippopotami. water buffalo, and duck-billed moles. It will be observed that some of these are permanently aquatic while others spend only

a part of their time in the water. Among our native mammals, the mink, otter, muskrat, and fisher invade the water for food, while the beaver uses the water for its home and for transporting food which it obtains on the land. The muskrat also frequently builds its home in the water.

All of these aquatic mammals are equipped for swimming, having webbed hind or front feet, or both; rudder-like tails; short hair; and stream-lined bodies. As indicated elsewhere, the positions of the eyes, nostrils, and the shapes of the heads are adapted to the lives they lead. They are to be seen only in the water or near it.

The terrestrial mammals are those which spend their lives on land. The running kinds have long, lithe bodies with slender legs which give them speed in flight. Many of them have long, movable ears which water forms lack. The true predators (wolves, foxes, coyotes, and shrews), which pursue victims which they devour, usually have long pointed snouts or muzzles which are adapted to following the trails of other animals by their sense of smell. Some of the predators (wildcat and cougar) are more or less sedentary and lie in wait for their victims. These lack the pointed muzzle, and their faces are somewhat flattened in comparison with foxes. All of the browsers and grazers (deer, elk, bison, goats, and sheep) are good runners, the goats and sheep being particularly adept in running over steep mountainous slopes.

There are a number of terrestrial mammals which forage on the surface of the ground. Many of these are short-legged and incapable of rapid flight. These usually have underground burrows into which they scamper when danger approaches. The gophers, badgers, groundhogs, native bears, ground squirrels, chipmunks, and many mice use subterranean shelters. Nearly all of the burrowing mammals have short legs and front feet which are well adapted for digging. Rabbits and hares frequently make excavations in the ground in which to place their young.

The moles are the truly subterranean mammals since they not only have underground shelters but also seek their food in the ground. The shrew and weasel, while not diggers, go into the ground for food, using the burrows made by other animals. They, therefore, possess some of the features of the burrowers on which they feed, such as long, serpentine bodies, short ears, and short legs.

The arboreal mammals are those which are structurally adapted

to climbing trees. They are, therefore, indigenous to forests. The squirrel, chipmunk, raccoon, opossum, marten, wildcat, cougar, bat, gray fox, deer mice, porcupines, and black bears are among the mammals that ascend trees. Some of these only climb trees to escape pursuers while a few seek their food above ground. Others have their homes in the trees and feed chiefly on the ground (raccoon, opossum, deer mouse). Some squirrels and deer mice construct outside nests in summer; while raccoons, opossums, flying squirrels, and squirrels live in hollow cavities which they sometimes line with soft material and leaves. The wildcat and cougar wait in the trees for their victims to pass beneath them, or they climb trees to look for possible victims. The gray fox, bear, and marten seek food in the trees at times.

Fig. 209. A mountain lion seeks safety in a tree. Courtesy Biol. Surv., U. S. Dept. Agric.

The arboreal mammals usually have feet with claws or retractile toes for climbing; prehensile tails which serve as an additional hand or bushy tails for balancing; and, as a rule, they have faces that are less pointed than those of terrestrial animals. The sloth of South America is the most highly specialized of all arboreal mammals. All of its limbs are constructed for climbing about on the branches of trees, and its face is rather flat.

While it is evident that many of the above mammals exhibit the ability to live in one kind of environment and yet seek food and shelter in another, there is, nevertheless, a definite series of structural adaptations which fit the various mammals to rather specific environmental settings. A knowledge of these struc-

tures makes it possible to interpret animals in terms of their environments.

The Classification of Mammals

The classification of mammals is based largely upon external features, internal anatomy, and teeth. Classification is more than a mere arrangement into groups for convenient study. The groups or units (Phylum, Class, Order, Family, Genus, and Species) include animals among which there are blood relationships, intimate and remote. The group arrangements are established on the bases of ancestry, development, and homologous structures. These indicate, to a large degree, the kinship of animals; and in the classification scheme the derivations of the various taxonomic units are implied. Among the members included in a family or genus the kinship is close, while in the larger units such as a phylum or order the members are most distantly related.

The vast differences between a horse and a mouse indicate that if a relationship does exist between them, it must be remote. On the other hand the similarities in structure between a squirrel and a woodchuck would suggest that these animals are more or less closely related to each other.

It is because of diversity that classification is necessary. When we consider the great diversity of animals with respect to size, form, and modified appendages, we are confronted with the problem of how a group of animals so identical in many respects could become so vastly different.

There are ten orders of mammals in the United States, and these include almost 1500 species found within the boundaries of the United States. In some of these orders there are numerous species, while in others the species are few. The distribution of all is determined by many factors.

Some factors involved in the diversity and distribution of mammals. To properly comprehend the technicalities of classification and distribution of the present-day mammals, it is necessary to study the topographical and attendant climatic changes that have taken place in the history of the earth from the time higher animals began to develop, and to consider the anatomical features of the ancestors of these animals, in so far as their fossilized remains are available. These changes include the isolation of continents and smaller land areas once connected with other continents

and mainlands by land bridges that have long since disappeared. The story of even the major changes that have been effected is too long for inclusion here, and the reader is referred to the references appended to this discussion.[1] However, it might be well to suggest the interesting possibilities in a study of this kind. There is no doubt that North America and Asia were once connected by a continental land bridge, possibly at Bering Strait. Over this bridge, land animals such as the horse which had its origin in Asia, and the camel which developed in North America, migrated back and forth. Fossils of early camels and horses are abundant in both continents. In this way numerous other species, as well, became disseminated over both continents. There is also evidence that North America and South America were formerly connected at three distinct places, including the Florida peninsula. Likewise, some of the West Indies were connected with the South American mainland as were, probably, the Galapagos Islands, although the isolation of the latter took place at an early date, which accounts for the unique fauna of these islands. Australia has a peculiar animal population because it was cut off from other land connections in ancient times. The isolated fauna therefore developed independently of other areas and without the influence of them produced a relict assortment of animals different from any other

Fig. 210. The black squirrel (*Sciurus carolinensis leucotis*). From Williams, *The Mammals of Pennsylvania.*

[1] Scott, William B. *The History of the Land Mammals in the Western Hemisphere* (Macmillan) gives an excellent account.

part of the world. The abundance of animal species within the arctic circle is accounted for by former land contiguities that were conducive to a widespread dissemination of species throughout the arctic region, the world over. On the other hand, the paucity of species in the Antarctic is explained by the absence of such land connections within the history of higher terrestrial animal forms. There is plenty of evidence to show that even some connection (Gonwannaland?) existed between Africa and South America. These connections provided highways for the wanderings of nomadic species of animals, and they account for the similarity of faunas in continents widely separated at the present time by great expanses of water.

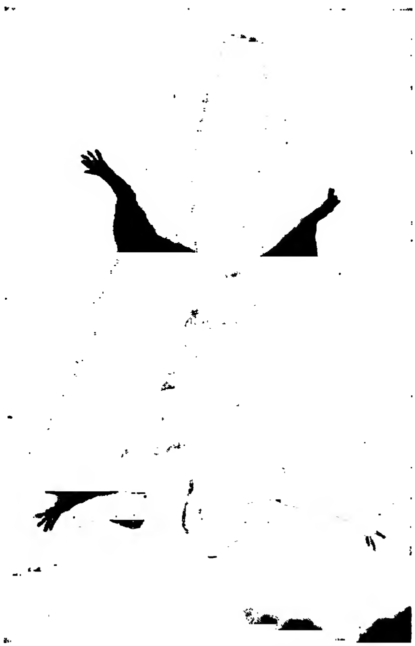


Fig. 211. The eastern flying squirrel (*Glaucomys volans*). From Williams, *The Mammals of Pennsylvania*.

Add to the changes effected by progressive migration and cross-breeding those brought about by glacial movements; and another side of the picture of animal diversification is revealed. When the glaciers descended, the inhabitants of the regions affected migrated, met the demands of a new environment by adaptive response, or were exterminated. With all of these influences there were combined the drastic effects of genetic mutations and natural selection. Hence the present diversity of form and structure to be seen in the mammals of today, as well as in other animal groups and plants, is not so mysterious after all.

Perhaps the most surprising feature of these changes is that they are continuing at the present time, as is evidenced by the changes taking place on the shores of all continents. The shore of New Jersey is receding, while that of Massachusetts is advancing. The levels of many inland bodies of water are constantly

lowering or rising. Lake Erie, for instance, is dropping from year to year; and the old shore lines, which mark the former levels, are visible at a distance of thirteen miles from the present margin of the water. Volcanic eruptions and earthquakes also play a part in altering the topography of the land, and these effects eventually bring about changes to which the animal and plant life must respond. An intensive consideration of the past history of the earth and its inhabitants will contribute a valuable background for the interpretation of present-day forms. With this knowledge, the diversity of form and structure which is so general in the mammals can be better understood.

It must be kept in mind that even local distribution of mammals will be determined by highways of and barriers to migration, as well as by the variety of ecological habitats available. Such factors as wooded areas, altitude, marsh land, streams and ponds, conditions of the soil, available food, temperature and humidity, enemies, and human activities all determine the kinds of mammals to be found in a given region.

The orders and families of mammals. The orders of mammals found in the United States are as follows:

(1) *Chiroptera*—the bats. Flying mammals with membranous wings. Body covered with fine, silken hair. Ears prominent. Feet small and adapted to clinging. Teeth numerous and equipped with many cusps for crushing insects, upon which all native species feed. Active only at dusk or after dark, hiding during the day in caves, barns, or hollow trees. Sometimes hang head downward from twigs or on the bark of trees. Most species hibernate in winter, although certain ones migrate southward at the approach of cold weather. Harmless and very valuable mammals representing three American families, only one of which, the *Vespertilionidae*, has a wide distribution. This family includes nearly all of the common bats such as the red bat, big brown bat, hoary bat, and yellow bat. The other families are the *Phyllostomidae*, including the leaf-nosed bat of California, and the *Molossidae* or free-tailed bats of the far western and southwestern sections.

(2) *Marsupialia*—the opossum. Pouched mammals with only one American representative, the common opossum which ranges from Florida to New York, Pennsylvania, and Ohio, and westward along the Gulf of Mexico to Texas and California. A primitive mammal with numerous teeth and prehensile tail. Nocturnal

habits, sleeping in its nest in a hollow tree during the day. Food consists of an omnivorous diet including insects, fruits, and small mammals. One family, *Didelphiidae.*

(3) *Insectivora*—the moles and shrews. Small mammals representing two families.

Family 1, *Talpidae,* the moles. Subterranean mammals with soft, velvety, and valuable fur. Legs short, fore legs greatly modified for digging. Eyes extremely minute and invisible. External ears lacking. Snout pointed and surrounded by fleshy tentacles in one species. Common mole, star-nosed mole, hairy-tailed mole, and numerous others. Species widely distributed. Food consists chiefly of insects, larvae, and small mammals.

Family 2, *Soricidae,* the shrews. Mole-like or mouse-like mammals lacking digging front feet. Body elongated and slender. Legs and feet slender. Snout pointed. Eyes and ears small. Carnivorous, feeding chiefly upon mice, birds, and insects. Habits chiefly nocturnal. Common shrew, pygmy shrew, water shrew, short-tailed shrew, and numerous other species distributed over most of North America.

(4) *Carnivora*—the flesh-eating animals including bears, weasels, skunks, foxes, badgers, wildcats, otters, minks, etc., representing six families.

Family 1, *Ursidae,* the bears. Large mammals with rather short legs. Feet plantigrade with five digits and equipped with strong claws. Tail short. Carnivorous dentition but food diverse. Terrestrial with the exception of the polar bear. Black or cinnamon bear, grizzly, and polar bears.

Family 2, *Procyonidae,* raccoons. Medium-sized mammals. Feet long and slender, front ones used as hands. Plantigrade. Muzzle elongated. Tail bushy with annulated rings of black. Nocturnal. Lives in woods along streams and marshes. Food consists of crayfish, mussels, frogs, insect larvae, birds, eggs, small mammals, and reptiles.

Family 3, *Bassaricidae,* cacomistles or ring-tailed cats. Raccoon-like in appearance but body much more slender. Claws short, curved, and sharp; semi-retractile. Digits webbed and hairy. Dental characters different from the raccoon. Food consists of birds, insects, and small mammals. Confined to the Southwest.

Family 4, *Mustelidae,* skunks, weasels, martens, minks, otters,

PLATE XXIV. Tracks of Native Mammals. 1. Muskrat; 2. Fox squirrel; 3. Woodchuck; 4. Skunk; 5. Meadow mouse; 6. Deer mouse; 7. Brown rat; 8. Weasel; 9. Rabbit; 10. Varying hare; 11. Raccoon; 12. Little chipmunk; 13. Shrew; 14. Mink; 15. Fox; 16. Red squirrel. From Williams, *The Mammals of Pennsylvania.*

badgers. Body slender. Legs short. Anal scent glands present in most species and highly developed in skunks. Fur valuable. Habits variable. Mainly carnivorous and predatory. The family has a wide distribution.

Family 5, *Canidae,* wolves, coyotes, and foxes. Medium-sized carnivorous mammals with long legs, slender bodies, and pointed muzzles. Dentition typically carnivorous with prominent canines. Feet digitigrade. Claws not retractile. Tail long and bushy. Red fox, gray fox, timber wolf, coyote.

Family 6, *Felidae,* the cats. Medium to large-sized carnivorous mammals with rounded heads. Limbs of moderate length. Feet digitigrade. Five toes in front and four behind. Claws long, sharp, retractile. Pads soft. Tail long except in lynx or bobcat. Mountain lion or cougar, wildcat or bobcat, jaguar, ocelot. Predators.

(5) *Pinnipedia*—seals and walruses. Large mammals with bodies modified for aquatic existence. Limbs fin-like or paddle-like. Tail rudimentary. Body tapering backwards. Ears small. Eyes large. Hair short and compact. There are two native families in this Order.

Family 1, *Otariidae,* California sea lion.

Family 2, *Phocidae,* Atlantic harbor seal.

Family 3, *Odobenidae,* walrus.

(6) *Rodentia*—rabbits, woodchucks, rats, mice, squirrels, chipmunks, gophers, beavers, etc. A large order with many representatives all over the United States. Terrestrial, aquatic, arboreal, and subterranean species. Dentition prominent with two long, sharp, and protruding incisors above and below. Teeth grow continually and are covered with enamel in front only. There are no canine teeth present and therefore there is a wide space between incisors and molars. The gnawing mammals.[1] The Order includes nine families.

Family 1, *Sciuridae,* marmot (woodchuck or groundhog), rock squirrel, ground squirrel, red squirrel, gray squirrel, fox squirrel, prairie dog, chipmunk, flying squirrel, pocket gopher. Form of body variable according to habits. Arboreal forms with bushy tails. Ground forms with slender tails, short legs.

Family 2, *Heteromyidae,* pocket rats and pocket mice, kangaroo rat, various species of pocket mice including the spiny Texas

[1] Rabbits and hares have been recently placed in another Order—*Lagomorpha.*

pocket mouse and the dwarf pocket mouse. Small rodents with fur-lined, external cheek pockets. The front legs have normally developed claws and the hind legs are somewhat elongated. The tail is as long as the head and body and occasionally longer. Midwestern, southwestern, and Pacific coast in distribution.

Family 3, *Castoridae*, beavers. Large rodents with thickset bodies; broad, flat, scaly tails. Habits aquatic. Found in most of North America where woodland and water conditions are suitable.

Family 4, *Cricetidae*, native rats and mice. Typical rat and mouse-like rodents of small size, including a great number of species a few of which are cosmopolitan. Grasshopper mice, white-footed mice, red-backed mouse, lemmings, rice rat, wood rat, meadow mice, muskrat.

Family 5, *Muridae*, Old World rats and mice. Black rat, Norway rat (brown rat), house mouse.

Family 6, *Zapodidae*, jumping mice. Form mouse-like; hind legs and tail greatly elongated. Locomotion is by kangaroo-like jumping. Internal cheek pouches present. Soles of feet naked. Northern United States to the Pacific coast.

Family 7, *Erethizontidae*, porcupines. Large, sturdy rodents with loose, barbed quills or spines among the hair on head, tail, upper parts of legs, and on the dorsal side of the body. Four toes in front and five behind. All feet equipped with strong curved claws. Found all over wooded North America north of latitude 40° and southward in the Rockies to the Mexican border.

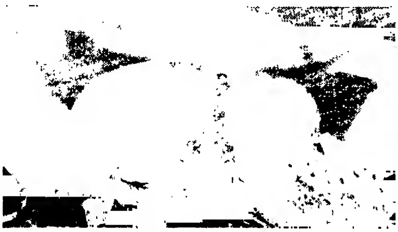
Family 8, *Ochotonidae*, pikas. Small rabbit-like mammals with broad, rounded ears which are not nearly so long as those of rabbits. Legs short, hind legs little longer than front ones. Tail not visible. These are sometimes included in another order because their teeth are different from those of the rodents. The pikas are confined to the Rocky Mountain section.

Family 9, *Leporidae*, rabbits and hares, including varying hare or snowshoe rabbit, cotton tail, jack rabbit. Medium-sized mammals with long ears and elongated hind legs. Tail short and hairy. A fairly large group with variations in size, color, and other characters according to geographical distribution. Distribution of the group rather general.

(7) *Artiodactyla*, the even-toed hoofed mammals, including peccaries, elk, deer, caribou, moose, pronghorn, antelope, mountain

Common Mole

Meadow Mouse

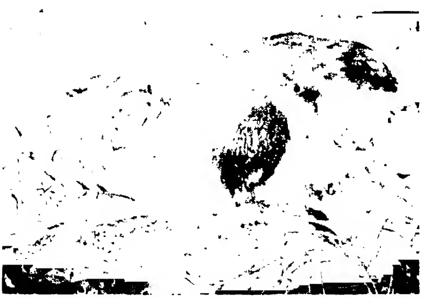


Short-Tailed Shrew

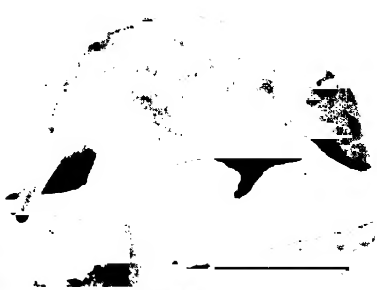
Deer Mouse

Long-Tailed Shrew

Woodland Jumping Mouse



Muskrat



Opossum

PLATE XXV. Some native mammals. Common mole from Biol. Surv., U. S. Dept. Agric.; all others from Williams, *The Mammals of Pennsylvania.*

goat, mountain sheep, and bison. Large-sized, digitigrade mammals with split hoofs. Terrestrial and herbivorous. The Order includes four families.

Family 1, *Tayassuidae*, peccaries. Pig-like ungulates of small size. Upper canine teeth pointed downward and lower ones with posterior edges knife-like (tusks). Snout pig-like. Four toes on front feet, three behind. Found in southwestern Texas, Arizona, and New Mexico.

Family 2, *Cervidae*, deer. White-tailed deer, mule deer, elk, moose, black-tailed deer, and caribou. Largest of American hoofed mammals. Males with deciduous antlers.

Family 3, *Antilocapridae*, pronghorn antelope. Both sexes with antlers bearing one lateral prong. A patch of long, white hairs on the rump makes them conspicuous in flight. The hairs are raised when the animals are disturbed. Distributed over western United States from Washington to Mexico and eastward to the Dakotas, Colorado, Oklahoma, and Texas.

Family 4, *Bovidae*, bison, or American buffalo. The species needs no description here. Found only in reservations. Mountain sheep and mountain goats belong to this family. Both are still obtainable in the United States in the western mountains from Texas to the Canadian border.

(8) *Xenarthra* (*Edentata*)—the American edentates or toothless mammals. The nine-banded armadillo is our only representative. Contrary to its name, teeth are present. The armadillos are small mammals with the skin ossified into a shell-like covering above. The shell is composed of numerous small hard plates and has nine laterally extending bands across the back. The head is small and pointed and with a hard shield above. Ears long and naked. Tail long and covered with hard plates. Legs short. Front feet with four claws, the middle two excessively developed for digging. Food consists of insects which it obtains by digging. Found in the United States only in Texas, Arizona, and southern California. Active at night only.

Family 1, *Dasypodidae*, armadillo. There is only one family in this Order.

(9) *Cetacea*—whales, dolphins, and porpoises. Aquatic mammals ranging in size from medium-sized porpoises to gigantic whales 103 feet long. Seldom seen. Confined to the oceans with characteristic species on Atlantic and Pacific coasts.

(10) *Sirenia*—manatees, dugongs, and sea cows.

Family 1, *Trichechidae,* manatees. Large, heavy, round-bodied, aquatic mammals with upper lips cleft in middle. Nostrils above with automatically opening and closing fleshy plugs. Found only on Florida coast northward to Daytona. Food consists of aquatic vegetation.

Representatives of the native families of mammals are shown in Plates XXV and XXVI.

The Habits, Life Histories, and Characters of Native Mammals

The marsupials or pouched mammals. The marsupials or pouched mammals have but one representative in North America, the common opossum which ranges from Florida to New York in the East and westward along the Gulf to Texas. While there are several marsupials in South America, the opossum is the largest American species; and the kangaroo of Australia is the largest in the world. The little murine, or mouse opossum, of South America which is frequently imported in bananas is the smallest American marsupial.

The opossum is the most primitive American mammal. It has a naked, prehensile tail and possesses fifty teeth which is considerably more than the normal number for mammals. It is omnivorous in its diet which includes fish, fruit, birds and their eggs, insects, vegetables, frogs, and small mammals. It nests in hollow trees where it sleeps during the day, and spends considerable of its time at night roaming about on the ground in search of food.

Young opossums are born in a very immature state about twelve or thirteen days after mating. The five to fourteen young are so small that a tablespoon will hold more than twenty of them. Unlike most mammals, the young lack the usual placenta and umbilicus; and although blind and seemingly helpless when born, they sometimes reach the pouch or marsupium of the mother by their own efforts. The mammae are situated in the marsupium, and to these the young attach themselves and hold on until fairly well developed. The opossum feigns death when cornered or attacked, and this accounts for the expression "playing 'possum." Most marsupials are confined to Australia where the kangaroo is the most conspicuous species. The worst enemies of the opossum are foxes and great horned owls.

The bats. Bats are familiar animals to most persons. They are the only truly aerial mammals. While they are more frequently seen flying about at twilight or after dark, they rest during the day in caves, hollow trees, lofts, or chimneys; or they cling to the bark or twigs of trees. Here they sleep, head downward as a rule, clinging to objects with their tiny feet and sometimes with the hooks on the wings.

At night they emerge and fly about, feeding upon insects which they capture in flight. Bats have numerous sharp teeth which are equipped with many cusps for crushing the chitinous bodies of insects. Their large membranous wings are really modified front feet, or arms, in which the bones of the arms and fingers are much elongated, forming a framework over which there extends a membrane. The membrane is attached to the sides and extends from the fore limbs to the hind limbs. Each wing is supplied with a small, hook-like claw on the bone that corresponds to the thumb. This claw enables them to climb about over rough surfaces. It is the use of this claw that gives to bats the name Chiroptera, which means hand-winged.

Bats are true mammals, being covered with soft hair and possessing thoracic mammary glands through which the young are nourished. The number of the mammae or breasts varies in different species and is of value in determining specific identities. The young cling to the bodies of their mothers and are not tucked in nests, as a rule. Many people seem to think that bats are mouse-like; and in a way they are—in that they have prominent ears and a sleek coat of hair. However, aside from this rather superficial resemblance, the usual characters of mammals in general are the only true likenesses.

Most of the northern species of bats hibernate in caves, hollow trees, or other protected places during the winter months; but there are some species which migrate to the Southland as do birds when insect activity ceases. A single large cave may harbor thousands of hibernating bats. Sometimes they collect in clusters for warmth, and they sleep until summer returns, although they are easily awakened. When they are disturbed in midwinter or early spring, they fly about and exhaust their reserves of energy; and they usually starve before food is available.

Bats are objects of numerous superstitions, probably because of their rather retiring and nocturnal habits. To most people

they suggest something eerie or "spooky," and they are often associated with terrifying experiences. They are accused of carrying and disseminating bedbugs and other pests; but the writer has examined thousands of hibernating bats, and he has yet to find the common household bedbug on them. Like all other animals (including many humans), bats have ectoparasites including hippoboscid flies on them. But the tales about their being disseminators of pestiferous parasites are fallacious. It is also certain that bats are not in the habit of "looking for someone's hair to get tangled up in," as many people suppose.

On the whole, bats have fewer objectionable qualities than any other mammals. The service they render in devouring beetles, flies, moths, and mosquitoes is of inestimable value. Bats are harmless creatures, and the common fear of them is entirely unjustified. In fact they should receive our protection.

Bats seem to possess a sixth sense. They can fly through a maze of tangled string without entangling themselves. Sometimes, when they accidentally get into a room where the light temporarily blinds them, they may be seen to fly swiftly across the room as though they would kill themselves against the opposite wall. They fly close to the wall but never hit it. This is explained by the fact that they have well-developed ears and a keenly specialized sense of hearing. It has been suggested that they catch the echoes of their flying noises which are reflected and are thus guided in their flight.

All of our native bats are insectivorous as has been suggested, but in the tropics there are fruit-eating bats which have a wing spread of more than twenty inches and a carnivorous species which has a spread of forty inches. There are also the small, blood-sucking vampire bats which suck the blood from mammals and even from human beings.

There are many species of bats in the United States. Some of them can be identified in flight, but the great majority of them must be examined at close range before authentic identifications can be made. The more common kinds are: red bat, big brown bat, silver-haired bat, little brown bat, and the pygmy bat. The different species show interesting habits of flight. Some of them appear before dark, and others wait until late before they begin their flight. All bats are graceful fliers; and while all of them feed on the wing, several species frequently swoop down and pick up

insects that float on the surface of water in ponds. The expression "blind as a bat" has no true significance since all bats have well-developed eyes. They may be confused or temporarily blinded by bright lights however. The enemies of bats are chiefly owls.

Practically all of our native bats belong to a single family—*Vespertilionidae.* The blood-sucking vampire bats (*Phyllostomidae*) are occasionally found in the extreme Southwest.

The insectivores (moles and shrews). The moles (*Talpidae*) are small, insectivorous mammals which are remarkably adapted to burrowing through loose soils, in which they find insect larvae, beetles, pupae, earthworms, and mice, upon which they feed. The moles have a primitive dentition (36 to 44); long, pig-like snouts; soft velvety fur; invisible eyes and ears; and highly modified front feet for digging. Because the mole moves forward and backward in subterranean tunnels, the fur strokes either way. The front feet are large and hand-like. The tails of all species are shorter than the body length. The moles, living beneath the surface of the ground, lack the countershading which is characteristic of most animals; and the coloring is uniform all over the body. Their short legs make it difficult for them to travel over the surface of the ground with any degree of speed, but their progress through the earth is surprisingly rapid. They are seldom seen above the ground however. Most of them burrow close to the surface of the ground, and their movements may sometimes be seen as the dirt is elevated in serpentine mounds. Contrary to common belief, the mole does not eat vegetable matter; and its depredations in gardens are due to the disturbance of the growth processes rather than to the destruction of the plants themselves. They sometimes do considerable damage to golf greens and gardens by their burrowing. Moles rear their litters of from three to six young in subterranean rooms connected with a series of ramifying burrows. There are many species of moles in the United States, the common mole having a wide range in eastern North America.

The star-nosed mole of the East is one of the most spectacular members of the family. It has a ring of twenty fleshy tentacles on the snout. In the star-nosed mole, and possibly in other species, reserves of energy are stored in the tail. The tail becomes considerably swollen before winter, and this reserve is drawn upon during the long, unfavorable period when food is scarce or unobtainable. It is interesting to note that the tail in all species is a

tactile organ and guides the mole as it backs through a tunnel. Other more or less common species include Brewer's mole, hairy-tailed mole, and the western mole. The weasels, skunks, foxes, shrews, snakes, and owls are their enemies.

The shrews (*Soricidae*) are small mouse-like mammals with elongated muzzles and small but visible eyes and ears. The skull is long and narrow. The teeth, numbering thirty-two, are highly specialized. The color is brownish above and paler beneath. The shrews are courageous and active little killers which prey upon insects and their larvae, mice, and other small mammals. A shrew will eat two and one-half times its own weight in a single day. Shrews are nocturnal in their habits, and they invade the burrows of mice and moles in search of food. They remain active all winter and tunnel through the snow close to the ground. Because of their small size and their stealthy habits, the shrews are little known. None of them are good diggers, although the front feet are very slightly modified in a few species. Their nests are placed in rock piles, in hollow logs, or in thick grass. The young number four or five, and several broods are produced each year. There are variations in size, shape, and tail length in the American species. The commonest species are long-tailed shrew, short-tailed shrew or mole shrew, pigmy shrew, smoky shrew, and water shrew. The pigmy shrew is the smallest North American mammal. The most important enemies are foxes, weasels, owls, skunks, and moles.

The carnivora (dogs, wolves, foxes, bears, minks, weasels, wolverines, martens, raccoons, skunks, otters, lynx, badgers, cacomistle, wildcats, jaguars, ocelots, cougars). These are the flesh-eaters, and they are characterized by large, prominent, canine teeth.

The foxes, wolves, and coyotes (*Canidae*) are medium-sized carnivores with dog-like forms; pointed muzzles; long, well-developed, and somewhat bushy tails. They are active, pursuing predators, preying chiefly upon small mammals and birds. Wolves sometimes travel in packs and kill larger animals such as deer, moose, and caribou.

The gray fox is reputed to be a great destroyer of rabbits, grouse, quail, and pheasants, as well as smaller species of birds and mammals. It is capable of climbing trees where it captures wild turkeys and domestic fowl which rest on the lower branches at night. When

pursued by dogs, the gray fox "holes up" or ascends a tree. It is usually an inhabitant of wooded areas.

The red fox, of which the silver and black foxes are varieties, has a wide geographical range. It is usually more abundant in pastoral regions where it does much damage to poultry and young sheep. Unlike its cousin, the gray fox, the red fox cannot climb trees; and when pursued by hounds, it will cover a distance of twenty miles or more. In the chase it breaks its trail by wading up streams and by jumping from one tree stump to another. In this way it confuses the dogs by "backtracking." The red fox is the species used by foxhunters. Its persistence in numbers in thickly populated and open regions where dogs are numerous is a testimonial of its sagacity. The fur of the red fox is quite valuable. Some states pay bounties on the foxes, which are classed as vermin by hunters and sportsmen. In Pennsylvania, where game animals are abundant, bounty is paid only on gray foxes. Foxes live in caves, hollow tree stumps, and in lairs which they dig. The young number from four to nine and are cared for by both parents.

The kit foxes of the Middle West are small subspecies of the red fox.

The coyote or prairie wolf is a small, slender wolf which inhabits the midwestern sections of the United States where its howl and bark are characteristic sounds at night. Its sheep-killing proclivities have resulted in organized attempts at its extermination. Coyotes are sometimes taken in the eastern states. Tourists returning from the West sometimes bring coyote pups back with them. These escape when nearly grown, and they respond to the "call of the wild." Quite frequently they breed with police dogs, and a pack is formed. In Pennsylvania recently one of these packs became so destructive that an organized hunt was arranged. Eight or nine animals were killed; and among them were dogs, hybrid crosses between dogs and coyotes, and true western coyotes.

The timber wolf is a much larger and heavier animal than the coyote. It is somewhat gregarious and travels in packs. The entire pack unites in bringing down a large victim such as a deer or caribou, and then the pack fights viciously over the carcass. If one of their number is seriously wounded in the hunt, its fellows do not hesitate to devour it. Wolves have become quite rare in recent years in all sections of the country.

The cats (*Felidae*) (jaguar, cougar, ocelot, wildcat). The cougar, puma, panther, or mountain lion is the largest of the unspotted cats. It is one of the most formidable of American predators. It was at one time found all over the United States but is now extinct in many places, especially in the northeastern sections. It is still abundant in the mountains of the West and in the Florida Everglades. It is a powerful enemy of deer.

The jaguar is largely a tropical and subtropical animal, but is occasionally seen north of the Mexican border. Like the cougar it is a shy and stealthy hunter of small and large mammals. It usually flees from humans; but when surprised or cornered it is a dangerous beast to encounter. Beebe says that it takes twenty square miles of jungle to feed a single jaguar. It is surprising how quickly a jaguar disappears in the jungles, to which its spotted pattern seems to be an adaptation. The writer has encountered several jaguars in his Amazonian travels and he can testify to their cowardly habits.

The ocelot, which is much smaller than the jaguar, being little larger than a large house cat, is a much more courageous animal than the jaguar, as far as humans are concerned. In trekking over a jungle trail at night, the writer has been followed on several occasions by an ocelot. The cat crossed the trail behind him and before him several times but always at a distance that would insure its own safety. It is very doubtful if any of the South American cats would attack a human being except when they are wounded or cornered.

The wildcat is a widely distributed bob-tailed cat with a vicious nature. It is a sedentary forest hunter, and lies in wait for its victims which range from small mammals and birds to deer. The wildcat, lacking the pointed muzzle, cannot follow a trail as does a fox. It usually rests upon the lower branches of a tree and pounces upon animals that pass beneath. It is larger than a house cat and differs from the cat in having the short tail and pointed ears. The wildcat lives in a den of rock, frequently along a cliff, and is almost entirely nocturnal in its habits. The Canadian lynx differs but little from the wildcat, but is more northern in its range.

The bears (*Ursidae*) include the cinnamon or black bear, which has several varieties, such as the kermode bear and the glacier bear; and the grizzlies.

The bears are the largest of the American carnivorous animals, and are characterized by rudimentary tails; long hair; plantigrade feet with five toes and long claws; legs rather stout; body thickset and robust. In the United States there are two real species of bears: the black, brown, or cinnamon bear; and the grizzly bear. The polar bear and the Alaskan bears are northern species. As the several names indicate, the black bear is extremely variable in color. Unlike other bears, the black bear has an arched spine, and is the only species that can climb trees.

The bear is a rather near-sighted and curious creature, and for these reasons frequently allows people to get close to it. It feeds upon small mammals, nuts, berries, and other fruits. It is especially fond of honey and frequently robs bee trees. The black bear is quite generally distributed over the United States and is abundant in some places. Hunters killed 960 black bears in a single open season in Pennsylvania in 1929.

The play instinct is strongly developed in the black bear, and it is known as the clown of the woods. However, it may be quite dangerous, especially when wounded; and a female with cubs is unpleasant to encounter.

The grizzly bear is much larger and more ferocious than the black bear. It is more commonly found in the region of the Rocky Mountains.

The bear is active all winter in mild regions, but in the northern sections it hibernates when the ground is covered with heavy snow. When it is ready to retire from activity, the bear makes an excavation under the roots of a tree, scrapes in some leaves for a bed, then goes to sleep. Its sleep is not the comatose state of the real hibernators however; and it is easily aroused. It seemingly sleeps with one eye open. The cubs numbering one or two, seldom three, are born during the winter sleep of the mother. When the young are born, the female forces the male to keep away.

The raccoons. The raccoon (*Procyonidae*) is represented by a single species which is found in all sections of the country south of latitude 50°. It is a woodland animal which lives in hollow trees near streams or lakes as a rule. It forages along the streams at night, feeding upon crayfishes, frogs, and mussels. A well-beaten path along a small stream is usually the sign of the activity of a raccoon which lives in the vicinity. It also feeds upon reptiles, birds, fruits, insects, and their larvae which it digs from dead

wood. When a raccoon leaves its nest in a hollow tree, it does not descend the tree in which it lives but it crawls out on the branches and descends neighboring trees in order not to reveal the location of its home. The raccoon is the monkey of the woods, and pet specimens exhibit a great curiosity.

The tail of the raccoon is ringed with black, and there is a black mask across the face. It is remarkable that the animal can persist in the face of the demands for "coon skin" coats. Trappers and coon hunters exact a tremendous toll from the numbers of these mammals every year. The color varies somewhat in the different sections of the country where it is found, even black forms being fairly common.

The raccoon is sometimes called the wash-bear because of its habit of washing its food before eating it, when possible. There are five toes on all of its feet, and it has forty teeth. The animal is plantigrade. The litters number four or six. The raccoon hibernates in the northern sections of the United States.

The seals (*Pinnipedia*). The seals are really aquatic carnivores with the dentition typical of the flesh-eating mammals. The digits are webbed so as to form an effective swimming paddle. The front limbs are near the front end of the body and the hind limbs are directed backwards. The feet are equipped with strong curved nails. The hind legs are helpless on land. The body tapers backwards and is covered with a fine, compact coat of hair and the skin has a great commercial value. Seals feed almost entirely upon fishes and squids. Seals spend considerable time on exposed rocky shores, and they breed upon ice floes or in isolated rockeries on inaccessible coasts or islands. A few species reach the shores of the United States, although they are mostly confined to the northern regions. They are gregarious in their habits.

The weasel family (*Mustelidae*) (weasels, ferrets, skunks, otters, minks, martens, and wolverines). These are all carnivorous animals of from small to medium size. All of them are predators and their habits are somewhat similar. The ferrets and weasels are terrestrial species which prey upon poultry, rabbits, rats, mice, and birds. The weasel is particularly destructive and seems to kill for sport. A single animal may slay a whole flock of turkeys in a single night. It chews the head of each animal killed, apparently for the brains. In most sections, the weasel is considered an enemy of beneficial and game birds as well as of the small

game animals, and bounties are paid upon the several species. However, the weasels destroy great numbers of destructive rodents. The small least weasel, which measures about seven inches in length, is probably beneficial although it destroys some small birds. The weasels in the northern part of the country become white in winter and then regain their brownish hues in the spring. There are many species of weasels distributed over practically all of North America. The fur of most of them is valuable. Weasels nest in hollow logs, rock piles, and in the deserted burrows of other animals.

The fisher and marten are closely related, but the latter is much the larger. The marten is the arboreal member of the weasel family and is restricted to forest areas in which it feeds upon birds, squirrels, chipmunks, insects, and berries. The fisher is darker in color than the marten, being, at times, almost black. It sometimes forages in the water and feeds upon fish, frogs, and birds.

The mink is one of the most valuable of the fur-bearing animals but trappers have greatly reduced its numbers and it is very scarce in most eastern states. The mink frequently takes to the water in feeding; and in addition to devouring water animals it feeds upon birds, reptiles, small mammals, and even poultry. It is much more generally distributed than the fisher and is found in the whole of North America.

The otter is the only truly aquatic member of the family. Its body is stream-lined, and its four feet are webbed for swimming. The tail is long and rounded, and the eyes are situated near the front and top of the head to enable it to look about without exposing much of its body when emerging after a submarine expedition. It feeds upon beavers, muskrats, ducks, crayfish, and frogs. The otter sometimes preys upon poultry and land mammals. Otters often play for hours by sliding down a muddy bank into the water.

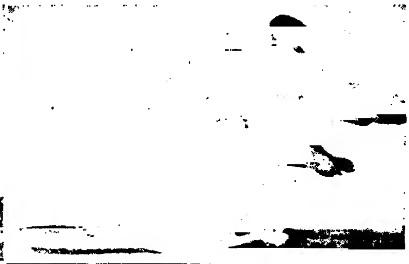
The wolverine is largely a northern animal and has long hair. It is the largest member of the weasel family, attaining a length of forty-one inches and a weight of almost thirty-five pounds. It is extremely rare in the United States.

The skunks are the most prominent and most avoided members of the family. While all members of the weasel family have pronounced odors due to the presence of scent glands, in the skunks these glands are highly developed; and the secretions are very offensive, as everyone will testify. They serve as an efficacious

Otter

Star-Nosed Mole

Red Fox

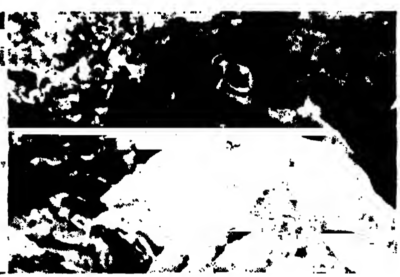


Cave or Wood Rat

Eastern Chipmunk

Least Weasel

Badger



Pika

PLATE XXVI. Common American mammals. Badger, star-nosed mole, and pika from Biol. Surv., U. S. Dept. Agric.; all others from Williams, *The Mammals of Pennsylvania.*

means of defense against most enemies of skunks, although great horned owls do not hesitate to attack them. As a rule, however, the defense of the skunk is the most efficient of all native mammals; and as a result of its security the skunk has lost its ability to intelligently discriminate among dangers. Thousands are killed on the highways by automobiles each year. Skunks feed upon insects, small mammals, birds, eggs, poultry; and they dig in the ground for larvae. The conspicuous black and white colors may be arranged in spots and dorsal stripes of varying widths. Sometimes the color is solid white or black. The conspicuous pattern is interpreted by some biologists as a warning to other animals. The skunks are rather generally distributed over the country, and in some sections they are very abundant. The young are born in litters of as many as eighteen or twenty and it is an interesting sight to see a mother skunk being trailed across a field by a large litter of young ones arranged in single file, with tails erect.

The badger is a midwestern animal that lives in burrows. It is a broad, somewhat flattened, heavy-bodied animal with long shaggy hair. The front claws are very long, and it can dig rapidly. It feeds upon ground squirrels, gophers, rats, mice, and birds. The badger is a slow-moving animal and most of its victims can easily outrun it. It therefore has to secure most of its food animals by digging them out of their burrows. The badger is a worthy adversary for any dog or fox.

All of the *Mustelidae* have the scent glands located on either side of the anus.

The edentates (*Xenarthra*). The armadillo is the only native member of this group and is indigenous only to limited sections of the United States. It is one of the most curiously modified mammals on earth. Its head, body, and tail are covered with hard, bony plates; and when disturbed the animal rolls up in such a way that its softer parts are protected. The armadillo has a pointed snout, digging front legs, and it feeds upon insects and their larvae which it digs from the ground.

The rodents. The rodents comprise one of the largest and most interesting groups of mammals; but as a group this is also one of the most destructive. It has already been suggested that the long incisors, which continue to grow throughout the lives of the animals, are the most characteristic features. The gnawing teeth have resulted in the formation of a typical head shape which is

unmistakable; and rats, mice, beavers, woodchucks, and all other rodents can easily be identified on sight.

A brief discussion of the families follows:

The squirrels (*Sciuridae*). There are many species and subspecies of squirrels throughout the United States. All of the arboreal forms have bushy or very hairy tails which serve as balancers. The gray squirrel is abundant in the East. It has two color phases including the black which is erroneously considered as a species at times. The gray squirrel is an inhabitant of woodlands and is active all winter.

The fox squirrel has several phases. It is much larger than the gray squirrel and is distinctly yellowish underneath both the body and the tail.

The red squirrels are widely distributed over the country, and the colors are somewhat variable in the various sections. They are the smallest of the tree squirrels and are held in bad repute because of their destruction of birds' eggs and young. They are the most inquisitive of the tree squirrels and considerably less shy. Their noisy chatter is known to campers everywhere. Unlike the fox and gray squirrels, the red squirrel stores up seeds, fruits, and nuts during the summer months.[1] Upon this supply it subsists during the long unfavorable northern winters, although it does not hibernate. Some of the red squirrels are called chickarees.

The flying squirrel is so named because of its ability to glide gracefully from heights and land easily on the ground or on the lower limbs of trees. It possesses a peculiar hair-covered membrane of skin on both sides of the body between the front and hind limbs. The skin flap is attached to both limbs as far as the wrist and ankle; and when the animal is ready to "fly," the legs are extended, and the membrane spreads like a sail. The creature then soars through the air in a volplaning sort of flight. The strong hind legs enable the animal to "take off" with a force that carries it to a great distance. The tail, which is thin and flat, is turned upwards as the animal alights and thus makes the landing easy. The stretched membrane serves the same purpose as the wings on an airplane.

There are numerous subspecies of flying squirrels, and they are distributed throughout the wooded sections of a large part of the United States. There is considerable variation in the size and

[1] The gray squirrel does bury nuts and frequently stores some food.

coloration of the various kinds. In color the eastern flying squirrel is grayish brown, with a rusty tinge above; underneath it is white. The skin flaps on the sides are of a dark brown. The head is blunt and rounded, and the ears are short. The tail is about as long as the head and body together. The hair is soft and of medium length.

The creature makes its nest in a tall tree and lines it with dried leaves. As a rule, flying squirrels live in communities; and a number may live together in a hollow tree. However, each pair usually stores up its own winter supply of food which is concealed in another tree from the one in which the nest is placed. There are usually from three to seven young.

The flying squirrel is a nocturnal animal, and possesses large glowing eyes. It is omnivorous and eats nuts, insects, and birds' eggs. There is also some evidence to indicate that it will, occasionally, eat young birds. The animal is easily tamed and makes an excellent pet, but it avoids bright light, and will crawl under one's coat or into his pocket to avoid it. A full-grown animal may attain a length of ten or twelve inches. The males and females are alike, and there is little seasonal variation.

The ground squirrel is a terrestrial, burrowing species which has a large body and a short tail. There are numerous subspecies of the ground squirrel distributed throughout the West, Middle West, and Southwest. As a rule they inhabit treeless areas such as plains and deserts; and they feed upon seeds, roots, insects, and birds (rare). Like the groundhog or woodchuck, the ground squirrel seldom wanders far from its burrow and makes a dash for its subterranean den when danger approaches. The dull coloration is constant throughout the year, although in some sections it is striped or spotted. The ground squirrel is also known as the spermophile, gopher, and digger.

The woodchuck, groundhog, marmot, or whistle pig is a common and widely distributed terrestrial relative of the tree squirrels. It lives in underground burrows which are located in rock piles, hillsides, and ravines. The openings of the burrows are conspicuous because the animals leave the barren, excavated material just before the entrances. Sometimes whole colonies of them make their burrows close together, although each burrow has its own inhabitant.

The woodchuck feeds upon green, succulent vegetation; and

because of the absence of food in winter and because it could not possibly make long migrations, it hibernates during the long, cold periods. Down below the frost line the animals, fattened during the summer feeding, go to sleep. Usually two of them cuddle together, and during hibernation they are in a comatose state. The vital processes are reduced to a minimum; the heart beat and respiration are slowed down to an almost imperceptible point. The reserves of fatty tissues, built up during the summer months, furnish sufficient nutriment for the long period of inactivity. The woodchuck is edible although it is seldom eaten except by blacks and woodsmen. The animal is objectionable, not because of what it eats but because its burrows menace running horses and cattle; and they make cultivation more difficult. The fur is of little value.

When disturbed the woodchuck attempts to reach its burrow; it seldom wanders far away because its short legs make it impossible for the animal to run swiftly. When cornered it is a worthy adversary for any dog, and its chattering teeth and whistling sounds are expressive of its anger.

In the East, the woodchuck, or the groundhog as it is more commonly called, is supposed to emerge from its burrow on the second day of February; and if the sun is shining so as to cast a shadow, the animal, frightened by its shadow, immediately goes back into its den where it remains for an additional six weeks. Its retirement is supposed to be followed by six more weeks of winter. This legend is connected with the idea that a warm February prognosticates a late spring. There are many people who still judge the approaching spring by the weather on "groundhog day." The woodchuck is very similar to the western ground squirrel, and in reality it is a ground squirrel itself.

The chipmunks nest underground, usually concealing the entrances to their burrows under rock piles, wood piles, and logs. The chipmunk does not make a well-beaten trail toward its den as does the woodchuck, but approaches the entrance by jumping. Excavated material is carried away so as not to reveal the location of the burrow.

The chipmunk has many subspecies and varieties throughout the eastern and western sections of the country. In the West the species belong to the genus *Eutamias,* and in the East the genus *Tamias* has several varieties of the one species, *striatus.*

Chipmunks are characteristic little squirrels which are com-

monly seen running along rail fences, over stumps, or crossing highways with their tails erect. The coloration of both the western and eastern species varies considerably although the white stripes on the dorsal surface readily identify them.

Chipmunks are friendly little mammals which can be attracted to window sills with piles of oatmeal, raisins, or seeds, which they stuff into their cheek pouches in such quantities as to give them the appearance of having the mumps. They store up food for the winter and therefore do not become excessively fat as do woodchucks since they do not go into a comatose state of hibernation.

The prairie dog is another ground squirrel about one-half the size of a woodchuck. It is a burrowing species indigenous to the Great Plains region. Like its relatives, the woodchuck and ground squirrel, it sits up on its haunches to look around and to feed.

The pocket gopher (*Geomyidae*) is a familiar animal in the West and Midwest where its burrows are sometimes constructed in the middle of a gravel road. It is easily distinguished from other rodents by its fur-lined cheek pouches and broad head. There are two genera of gophers, *Thommomys* being far western and *Geomys* inhabiting the South and Midwest. They feed upon roots and bulbs underground and upon seeds and weeds above ground.

The pocket rats. The pocket rats and mice (*Heteromyidae*) are small rodents with external, fur-lined cheek pockets; slightly elongated hind legs; and a long tail. They feed upon seeds and live in brush piles, crevices, and under logs. Desert forms live in burrows. The pocket mice represent numerous subspecies distributed from Colorado westward and southward. The kangaroo rat, Texas spiny pocket rat, and the western pocket mice are native forms.

The beavers. The beaver (*Castoridae*) is one of the most interesting of our native mammals. Its spectacular habits reveal some remarkable adaptations. It is a swimmer, woodsman, and engineer. At one time the beaver enjoyed a wide distribution in the United States, but trappers have reduced its numbers to such an extent that it is rare in many sections. Under restocking and rigid protection in Pennsylvania the beaver became so destructively abundant that an open season was declared on them in 1933, and a total of nearly 7000 were taken.

The beaver is entirely herbivorous and feeds on the bark of

many trees. It is especially fond of the bark and twigs of the yellow birch, quaking aspen, poplar, and willow. Selecting trees of these species which grow close to the water, the beaver gnaws around the trunk near the ground until the tree falls. The branches are then removed, and ofttimes the main stem of the tree is cut into shorter lengths so that they may be pushed, dragged, or rolled into the water.

The great incisors, characteristic of the rodents, serve admirably in felling trees; and the endurable homes and dams show a practical knowledge of construction on the part of the animal.

In making the dam, the beaver selects a small woodland stream. Placing the longer and thicker stems and branches with their large ends up stream, the animal proceeds to carry mud and stones which are piled on the bases. Then the smaller sticks, grasses, and green branches are woven together; and the crevices are filled with mud and stones. The process of construction goes on until the dam is from four to six feet high. The water backs up and forms a good-sized pond of comparatively still water. In this pond water lilies and other aquatic plants grow, and the beaver feeds on the roots of these. When the trees along the water's edge have all been cut down, as happens when the colony is an old one, the beaver will frequently dig canals from the pond back to the woods. In these canals food is transported, and the necessity of dragging sticks and branches from a great distance over land is eliminated.

Usually there are supplementary dams placed above and below the main one to reduce the danger of breaking in rainy weather when the streams are swift and swollen. The dam below the main dam holds the water against the lower side of the latter and strengthens it.

There is generally a number of beavers in a colony; and when a break occurs in the dam, all of the members set to work to repair it. Each animal secures a stick on the shore and immediately swims with it to the break, where it is carefully placed. The sticks are placed so that water flows through them and floating material is caught as in a sieve and helps to plug the openings in the dam.

The beaver occasionally lives in burrows in the banks of the pond. These burrows extend for a considerable distance beneath the bank and generally have their openings below the surface of

the water. The burrow ends in a larger chamber several feet in diameter.

Usually the beaver constructs a mound-like home out in the water. This is made of sticks and mud and varies in size according to the number of individuals that live in it. The mound is conical and may be as much as eight feet high and forty feet in circumference. Inside the house and above the level of the water is a chamber in which the animal lives. The entrance to the hut is through a tunnel, opening beneath the surface of the water. The walls of the house are quite thick.

In winter the beaver partly hibernates within its house but ventures forth in mild weather. Food is stored in the pond for winter use, and the sticks from which the bark has been gnawed are used in reinforcing the dams.

The beaver is active day and night; and when swimming it slaps the water violently with its tail to warn others when danger approaches. It is also interesting to note that when a beaver is cutting down a tree it usually strikes the ground with its tail as a warning to others in the vicinity, when the tree is about to fall.

The beaver is the largest of our native rodents and may weigh up to fifty pounds. Its color is a dark chestnut brown on the back, blending to a lighter, almost cinnamon, brown beneath and on the sides.

The head is rounded and the nose is blunt. The large orange-colored incisors are quite prominent. The ears are short and the body is thick and heavy set. The legs are short and each foot has five toes. The second toe on the webbed hind feet has a double or divided claw. The broad flat tail is used as a rudder in swimming. The beaver has anal musk glands which secrete a strong-smelling fluid. There are two coats of hair, the outer being longer and coarser than the soft under fur. Both the females and the males are alike, and there is only a slight seasonal variation. The fur is quite valuable.

The total length of an adult beaver is about forty-two inches. The tail is about sixteen inches long and the hind feet measure almost seven inches.

Beavers are apparently monogamists and probably mate for life. Mating takes place in February and the young, numbering from three to eight, are born in May.

The native rats and mice (*Cricetidae*). The deer mouse or white-footed mouse is one of the commonest and gentlest of wild creatures to be found in the United States. It can be seen at almost any season in the woods and around barns and brush heaps. It is a common mammal on beaches where it constructs a crude nest under boards and logs which have been cast up by the waves.

The deer mouse is undoubtedly the most beautiful of all our native mice, being grayish-brown above and almost pure white beneath. It is larger than the house mouse and has a long, pointed nose. The ears are large, hairy, and prominent. The large eyes and long whiskers make its face attractive. As a rule, it may be handled with impunity if care is exercised in catching it; and within a few days it becomes as tame as white mice.

The home of this delightful creature is usually in the woods where it may add to a deserted bird's nest, making of it a large globular house of dried leaves, grasses, and vines, sometimes a considerable distance above the ground. It frequently happens that a number will occupy the same nest. Rural dwellings and barns are also utilized for home-making.

The deer mouse feeds upon seeds, nuts, and grains. Sometimes it stores large quantities of beechnuts, acorns, seeds, and corn for winter use. Summer camps are invariably visited by the deer mouse; and cereals, flour, and sometimes hide shoestrings are destroyed by it. It is an excellent climber and runs about over the branches of trees and shrubs. Some people call it the wood mouse.

This interesting creature is very prolific, and the female may have three or four litters of from three to six young in a year. On one occasion the writer surprised a number of deer mice in a rather open place. Three of them darted under a board. When the board was lifted, all three had their noses pushed into a shallow cavity which they had evidently dug in a hurry. Remaining absolutely quiet, they apparently thought they were escaping detection although their bodies were fully exposed. Needless to say, they were not further disturbed.

According to some writers, the deer mouse resorts to "singing" for its own amusement or perhaps for its mate. Who knows?

There are many species and subspecies of deer mice scattered throughout the whole of North America, including Fischer's deer

mouse and Rafinesque's deer mouse which are found in the northeastern states.

The lemming mouse is one of a great number of species distributed throughout the northern part of the United States. It is usually found in boggy regions, and it often uses the runways of meadow mice and is frequently caught with them. It resembles the meadow mouse so closely that it is apt to be mistaken for it. The lemming mouse may be distinguished by its short tail and by its grooved front teeth. The head is blunt; the ears are nearly hidden in the fur; and the legs are short. Its coloration is virtually the same as that of the meadow mouse, and the two sexes are alike. There is a slight seasonal variation, the summer color being a buffy gray or yellowish brown lined with black, and the winter color being a slaty gray. It is about five inches long when full grown.

The red-backed mouse, although usually preferring forest haunts, is frequently to be found in grassy fields where it hides under fallen logs or under stones. It really lives in underground burrows similar to those of field mice but usually selects dry, well-drained ground. Its nest is made of fine dry grass or moss and is placed within a chamber along one of its underground tunnels. Sometimes it nests in a hollow log; and on one occasion, the writer found a number of nests under a slab of corrugated iron. Several litters of young are born during the summer and each litter may contain from three to eight young.

The red-backed mouse is related to the field mice, but it seldom menaces crops as do the latter at times. The distribution of the numerous species and subspecies is confined to the northern wooded sections of the United States. The red-backed mouse is active both day and night and one may see it sitting up like a squirrel, holding seeds of berries between its fore feet and nibbling away in a characteristic manner. It eats beechnuts, acorns, and other seeds, in addition to young roots, bark and twigs of low shrubs.

The pine voles, of which there are several species, range from New England to Florida. The pine vole is sometimes called the mole mouse because of its burrowing habits. It lives almost entirely beneath the surface of the ground and has its fore feet somewhat modified for digging. The pine vole confines its activities to comparatively loose soil where it makes a series of tunnels which ramify in all directions. It frequently follows corn rows

and removes newly planted seeds. Occasionally it enters gardens and takes beans and other seeds. In addition, it does considerable damage to bulbs and the roots of growing plants. It is particularly destructive to sweet potatoes and tap roots.

The pine vole is covered with a soft, dense fur, which resembles the coat of the mole in texture. The general coloration is rusty brown above, and the under parts are whitish. The ears are short and inconspicuous, and the eyes are small. The tail is very short, totaling only about one-fifth of the body length. The legs are short; in some ways the animal resembles a shrew, but the rounded head, blunt nose, and typical rodent teeth, enable one to identify it easily.

The pine vole nests in a globular mass of dried leaves and grasses placed in an enlarged chamber along one of the subterranean tunnels. There are usually from four to six young in a litter. These are born in the latter part of March or in the early part of April. There are probably five or six broods in a year. The adult has a length of four and one-half inches.

The meadow mouse is abundant in all parts of Pennsylvania and, with its relatives, is probably the most abundant rodent in numbers and species on the North American continent. While our common species prefers moist meadows and swampy fields for its home, it frequently extends its burrows into cultivated fields. Occasionally it constructs a summer nest under a log or in a tussock of grass. While it sometimes bears its young in the nest above ground, as a general rule it has a chamber at the end of the underground burrow where four litters of from six to eight young are born during the year. The underground home is bedded with soft materials of all kinds. It rarely nests in houses or barns.

The meadow mouse establishes a series of runways which ramify in all directions from the entrance to the burrow. The runways are kept clear of sticks and other obstacles which might impede its progress in case a hasty retreat to the burrow is made necessary.

The meadow mouse feeds on growing grass, alfalfa, seeds, bulbs, root crops, and vegetables. When wheat and oats are harvested, great numbers of meadow mice congregate under the shocks and frequently do great damage. In the winter they often gnaw the bark around the bases of young fruit trees, and whole orchards of young trees have been killed by them. It is estimated that the

mice of the genus *Microtus* cause an annual loss of over three million dollars to American farmers.

The meadow mouse is about seven inches long, and the tail is not quite two inches in length. The body is somewhat heavier than that of the house mouse. The head is large and blunt; the ears are barely perceptible above the fur; the legs are short; the fur is long and overlaid with coarse hairs; the soles of the feet are naked; and each foot has six plantar tubercles.

The sexes are identical in size and color. The summer coat varies from a dark chestnut brown to a light yellowish brown above, with a number of coarse black hairs along the back. The under parts are a smoky gray slightly tinged with light brown. The feet are brownish. The tail is brown above and somewhat paler beneath. In winter the general coloration is duller and more uniformly gray.

The woodrat. The Pennsylvania woodrat is the most common eastern representative of a large number of species which are widely distributed. It lives chiefly in caves or in rocky crevices, although occasionally it burrows into the ground under the stump of a dead tree. Its nest is usually conspicuous because of its habit of placing all sorts of objects about the entrance. The nest is a huge affair, usually mound-like and constructed of sticks, dried grass, tufted seeds, rags, etc., crudely heaped together. The animal stores up quantities of seeds, pinyon and other nuts, haws, wild grapes, and other fruits. Virtually every deserted or unoccupied mountain cabin is inhabited by this curious creature which seems to take delight in stealing objects which could not possibly serve it in any way. Knives, forks, spoons, nails, and dozens of other articles left lying about a hunting lodge or cabin will disappear; and a careful search will reveal them to be hidden in all sorts of places. Dr. Hornaday says that "Seemingly, its chief object in life is to play practical jokes on mankind."

The woodrat is about the size of the ordinary house rat but it is easily distinguished from this loathsome species by its buffy slate-colored back and white underparts. Its tail, unlike that of the brown rat, is quite hairy and sometimes bushy. The underside of the tail is white. The eyes are large and black, and the ears are large and prominent. The long pointed nose and long white whiskers add a touch of dignity.

The woodrat is chiefly nocturnal and is a good climber. While

it is usually solitary, several may occupy the same nest. There are several litters of four or five young each year.

In some sections of the United States, and especially in Mexico, the woodrat is relished as a food. It is seldom a troublesome creature here, although it has been known to dig up pine seeds that have been planted.

The muskrat. The muskrat is quite generally distributed throughout the country, and it is sought by many persons for its valuable fur. In some places it is used for food. The muskrat is several times as large as an ordinary rat and has a rather thick body with short legs. The hind feet are partly webbed and otherwise adapted to swimming.

The long, scaly, nearly naked tail is flattened on the sides and serves as a rudder when the animal is swimming. The color is brown, but of various shades in different individuals. It ranges from a very light shade to a very dark one and is always darker on the back. The underside is whitish. The muskrat lives in swamps, ponds, and streams, and often burrows in the banks of the latter to construct its nest which is placed in a large chamber at the end of the burrow. While the chamber is always above the water level, the entrance may be beneath it. Muskrats also build large, dome-shaped huts two or three feet high and from five to six feet in diameter. These homes resemble somewhat those of the beaver. The houses are placed in the water away from the shore and are made of sticks and reeds. The interior of the house has a floor above the water level and is reached by diving from the outside. The muskrat does not hibernate but spends much of the winter within its house, although it frequently goes on excursions when the ponds are frozen; the writer has even seen it swimming beneath the ice. It feeds upon water plants, crayfish, mussels, and occasionally fish. It also stores up roots and other material for winter use and sometimes invades gardens where it feeds upon cultivated plants.

While the muskrat is chiefly nocturnal, it may occasionally be seen during the day sitting upon a stone or log feeding.

The young are born naked and helpless, and there may be from four to thirteen in a litter. Muskrat tracks may be seen in the grassy regions along ponds and streams where they have well-beaten trails. The front feet have four toes and the hind feet have five.

The creature has a total length of twenty-one inches, and the tail is almost one-half as long as the head and body combined. The hind foot measures three and one-half inches, and the creature may weigh as much as two and one-fourth pounds.

The Old World rats and mice (*Muridae*). The house mouse is a clever creature and it is found everywhere in abundance. Like the rat, it seems to prefer an intimate association with humans, and only its size prevents it from doing as much damage as the rat.

However, it succeeds in doing quite enough harm and should be continuously fought against. In addition to adding to the terrors of the female human population, the mouse persists in destroying foodstuffs and other materials in much the same manner as do rats.

Being of small size, it gains access to many situations; and even the seed in the canary's cage is devoured by it. Of course field mice frequently get into the house also, but in cities it is invariably the house mouse that one sees and hears. The house mouse nests in fur garments, old shoes, stove pipes, rag bags, and in almost every other sort of locality. It begins to bear when three months old and has a litter of from eight to ten every two or three months during the year. The nest is made of soft materials, such as hair, chewed newspapers, and rags.

The chief characteristics of the house mouse are: nose pointed; ears fairly large; tail quite long; body almost slender; color above, grayish brown with long black or yellowish hairs unevenly distributed; the underside is a slaty gray. Seldom more than six inches long, the tail being half the body length.

The Norway rat. Certainly the common rat is the most detested of native animals. The damage done by it amounts to millions of dollars annually, and it seems that nothing escapes its destructive ravages. Every sort of foodstuff, flooring, hot house plants, hulls of ships, insulation on electric wires, lead pipes, books, clothes, grains, field crops, chickens, birds' eggs, and even little pigs are destroyed by it. In addition to causing great damage to these and other things, the rat spreads fleas, filth, and disease. It is very prolific, having several litters of from eight to fourteen each year. The common rat is not a native of the United States, but was introduced years ago, having been brought here in ships. It is now quite generally distributed over the world and in some

countries causes a great mortality through its spreading of bubonic plague, tuberculosis, parasitic worms, typhoid, and other maladies.

It is a vicious creature and can inflict severe injuries. It nests in sewers, mines, and in the habitations of man. Sometimes it burrows in the ground, and its burrowing has been known to reduce the strength of building foundations.

It lines its nest with rags, cotton, or any other soft material which it can find or steal. It is normally a grayish brown on the upper part of its body and a grayish white below. Its ears and eyes are large, and its tail is as long as the head and body. The tail is almost naked, and the rings of overlapping scales are quite visible. It is about fifteen inches long when full grown. The snout is long, pointed, and bare at the end.

The black rat. The black rat was probably introduced before the common brown rat, but its numbers have been considerably reduced by the latter. In fact, the black rat has been completely exterminated in some sections by the brown rat.

The black rat is smaller than the Norway or brown rat, and on the dorsal surface it is a rather lead-colored black. The ventral surface is a slate-colored black. In addition to the difference in color, the tail of the black rat is much longer in proportion than that of the brown rat, and the scaly rings on the tail are even more prominent in the black rat than in the brown rat.

The habits of the black rat are similar to those of the brown rat except that it does not burrow under foundations.

The Alexandria rat. Another rat that may be found in scattered localities throughout the eastern states and in reduced numbers is the roof rat or Alexandria rat. It is smaller than the brown rat and proximates the size of the black rat. Its tail is more than half the body length, while the color is reddish brown above, blending into a grayish white below. It is apparently scarce.

The jumping mice (*Zapodidae*). The jumping mouse or kangaroo mouse may be readily identified by its extremely long hind legs; very long tail, which is one and one-half times the body length; short fore legs; and cheek pouches into which it can stuff considerable food.

It is yellowish brown in color and has a very perceptible black band running down the middle of the back due to the presence of many long, shining, black-tipped hairs. The sides are an even brighter hue, and the undersides and feet are white. The dividing

line between the upper and the undersides is sharply drawn. The tail is dark above and whitish beneath and is sparsely covered with hair. The head is of normal proportions, and the nose is pointed. The ears are small, and each foot has five toes.

The hair coat may seem rather coarse upon the first examination, but a closer observation will show that the main coat is short and fine and that the coarser long hairs are less in number.

The jumping mouse is well named, and it leaps in a manner similar to the kangaroo after which it is named. The tail serves as a prop and aids considerably in locomotion, as is shown by the fact that, when part of the tail is lost through accident, the animal has considerable difficulty in getting along.

The jumping mouse is a very inoffensive creature and feeds upon green vegetation, although it seldom becomes a menace in hay fields. It nests in a shallow burrow, in hollow trees, or beneath boards. The nest is globular and occasionally made of dried grass. The young are born in litters of five or six during the latter part of May or in the early part of June. In winter the animal digs a deep burrow in which it hibernates. Its total length is about eight inches, and the tail is about five inches. The hind foot measures 1.2 inches. There are several kinds of jumping mice in eastern United States. Other species extend throughout the country.

Like the meadow jumping mouse, the woodland form has a very long naked tail which it uses to good advantage in its jumping movements. However, this species is larger than the other species of jumping mice, and its ears are larger and longer. The woodland form has a paler color, becoming almost a buffy yellow above, and does not have an admixture of brownish gray on the under parts. The tail is tipped with white. There is also a distinct dental difference, in that the woodland jumping mouse lacks the upper premolar tooth which is possessed by the other jumping mice of the genus *Zapus*.

The woodland jumping mouse lives within the confines of the forests, in close proximity to a stream. The creature forages along the banks, and its footprints are commonly seen in the moist sand close to the water's edge. It is supposed to be entirely a nocturnal animal, and it is the most beautiful of the group of kangaroo mice. None of the jumping mice become pests inasmuch as they limit their diet to small seeds, nuts, grasses, and insects.

As winter approaches, the jumping mouse retires to a spherical

nest of leaves and grass which is placed below the frost line. In the nest the creature curls up and sleeps until spring returns.

The porcupine. The porcupine (*Erethizontidae*) is one of the most spectacular of our common mammals. The specialized development of many of the hairs into sharp spines or quills from a half-inch to three inches in length makes the defense a formidable one. When danger approaches, the porcupine lowers its head, arches its back, and appears to be rolled into a ball. The spines stand up and point in all directions and the tail is made ready for a vigorous sweep. When attacked, the tail strikes like a whip and the enemy receives a large collection of sharp penetrating needles. Since the spines or quills protect every portion of the body, its defense is almost impregnable. The spines are not firmly attached in the skin and when their free ends penetrate the skin of a foe, they pull out and remain firmly embedded in the victim, being held fast through the barbs at the tips. The porcupine does not "shoot" its quills, as many people believe.

While the quills are rather effective as defense structures, porcupines are not immune to all attacks; and many of them fall victims to eagles, owls, and wild cats. The porcupine is a solitary animal and is chiefly nocturnal in its habits. Being a true rodent, it is capable of doing considerable damage; and it frequently gnaws through doors and wooded walls. Campers who carelessly leave their axes within reach often discover the handles gnawed the next morning. Almost any wooded object that is handled by humans is subject to the workings of the porcupine. The creature apparently does this for the salt left by perspiration.

The usual food of the animal is various in character. It devours almost anything; in its woodland haunts it feeds chiefly upon bark, twigs, and fruits. It climbs trees readily. The porcupine is a sluggish animal and seldom attempts to make haste, depending upon its array of spines for protection.

The young, numbering from one to four, are born in May and are larger than the young of many mammals several times their size.

The favorite haunts of porcupines are evergreen forests, and they seem to prefer hemlock trees for food.

The rabbits (*Leporidae*). The common "cotton tail" rabbit is familiar to everyone. It is so abundant in Pennsylvania that it is often seen in city yards at night. Probably no other wild creature delights children as does the rabbit. It figures largely in their

Easter celebrations, and every child has listened many times to Uncle Remus' tale of "Brer Rabbit," and to "Bye Baby Bunting."

Rabbits inhabit the woodlands and the open fields over which they roam, chiefly at night. Hundreds are killed by automobiles on the roads each year, and thousands are shot during the open seasons in sections where they are hunted for sport. But they persist in great numbers, sometimes becoming quite a serious menace to orchards, gardens, and field crops. Their habits of chewing the bark from fruit trees in winter, and destroying alfalfa, vegetables, and nursery stock make it necessary to keep them in check.

The rabbit may nest in an underground burrow or in a shallow depression in the ground. Ofttimes the mother will line the depression with grass, dead leaves, and hair taken from her own body. In this cozy nest several litters of from three to six young are born each year. The nest is covered so well that it is usually hard to find. As darkness approaches, the rabbit ventures forth on foraging expeditions; it frequently becomes the victim of foxes, weasels, and owls. Sometimes during the day it sits and sleeps under a bush or in a "special setup" in deep grass. If disturbed, it scurries away in a zig-zag manner, its "cotton tail" showing conspicuously. Usually when danger approaches, the rabbit will thump the ground with its hind feet to warn others of approaching danger. The long hind legs are powerful and capable of rendering quite a kick. The rabbit differs from the hare in that it is smaller, has shorter ears and legs, and has a snowy-white undertail.

There are three common species of rabbits. All are quite similar in most respects, but the above-described form is more southern in its distribution. The other species, *Sylvilagus transitionalis* and *Sylvilagus floridanus mallurus*, are generally found in the northern section of the eastern states.

The snow-shoe rabbit or arctic hare is a rather large species, attaining a length of 19 inches, and it gets its name from its large broad feet, which seem well adapted to travel over deep snow. The hind feet are provided with long hairs which produce a snow-shoe effect. In winter the creature is a snow-white color, while in the summer it assumes a color varying from a grayish to a reddish brown. It is commonly supposed that the hairs turn color with approaching seasons, but it has been definitely established that the changes appear with molting.

The varying hares are chiefly nocturnal in their habits and rest during the day in crudely made beds of grass or in depressions in snow. Their activities increase in the early spring when mating begins. Frequently during the mating season a number of males congregate in the same place and indulge in bitter fights. When disturbed, they thump the ground with their hind feet as do most members of this group, probably to warn others of approaching danger. It is believed by some people that they call their mates in this way.

The species do not burrow into the ground but often make depressions in which the young are placed. There are usually from three to seven young. The nests are made of dry leaves and grasses to which the mother adds a lining of hair from her own body. The nest is placed under brush or in dense vegetation. The food consists of grasses, small plants, twigs, and buds. It is distinctly a northern species, although its range extends into the mountainous regions of Virginia where it seldom assumes the full white color. A number of the southern forms are subspecies. The most common enemies of the snow-shoe rabbit are the weasels, arctic foxes, and snowy owls.

The jack rabbits are very large and long-eared. Their hind legs are over-developed in comparison with the other rabbits, and they are capable of making unusually long leaps. While the jack rabbit has been introduced into several eastern sections by sportsmen, it has never thrived to any great degree. The jack rabbit is a very conspicuous form in the Middle West where it is considered a very destructive pest; and thousands of them are slaughtered annually in organized drives by agriculturists. There are quite a number of species of jack rabbits, in which the main differences are color phases. Most of them are confined to the section west of the Mississippi River.

The deer family (*Cervidae*). The Virginia white-tailed deer is certainly the swiftest and most graceful of the larger mammals. The long slender legs and lithe body make the creature beautiful to look at. The habit of raising the tail and showing the white underside when disturbed is considered a warning gesture to others in the vicinity, and has earned for it the name white-tailed deer.

Only male deer have antlers, and these are shed annually. As the young male grows the top of the skull develops two projections known as pedicles which serve as bases for the antlers. With the

increase in size and thickness of the skull, the pedicles spread and do not protrude so prominently. As the animal grows older, the antlers develop as a soft, pulpy mass covered with skin and fine, velvet-like hair. When the full growth is reached, the circulation of the blood is cut off and the antlers become hard and dry. The animal then removes the "velvet" by rubbing the antlers on the bark and branches of trees. This is usually done about the first of September. The size of the antlers depends at first on the age and physical condition of the buck; but later, age does not usually affect the size. There is no doubt that the food supply influences the growth.

At first the males are very careful of their antlers; but later, when the mating season arrives in October, the males will fight among themselves, often breaking their recently matured antlers. Sometimes they become inextricably interlocked, and death results. The deer is usually about a year and a half old when its first set of antlers is mature. The first set, as a rule, does not have prongs or branches; the animal is then called a "spike buck." In succeeding years, the number of branches increases; the best set of antlers appears when the animal is about five years old.

The female deer or doe gives birth to one or two and rarely three young in the early part of May. The young are called fawns and are possessed of the spotted forest pattern which seems to render a protection. The young do not follow the mother for the first few weeks; as they grow older, the hair coat develops in full. Then the spots gradually disappear until fall, when the coat of coarse hair is a uniform brown.

There are two pelage phases of our common deer. In summer its body is a reddish brown with the belly, underside, tip of tail, inside of legs, and throat patch white. There is a blackish spot on either side of the face and a whitish band across the nose. In winter the body color changes to a grayish or grayish brown. The hair also becomes longer and stiffer. The young are reddish brown with white spots which persist until the fifth month.

The Virginia or white-tailed deer is from five to six feet long, and the tail measures twelve inches. Its height at the shoulders is three feet, and a mature male may weigh from 250 to 300 pounds. The older bucks have enlarged necks during the mating season.

The deer is a ruminant or browsing animal, feeding entirely upon vegetable matter such as the buds, leaves, and tender twigs

of trees and shrubs. In winter when food is scarce they will devour rhododendron, laurel, hemlock, and bark. In extreme cases, the deer will visit open fields and even mingle among domestic stock on rural farms. It is interesting to note that the deer can survive on plants which kill sheep and other animals. In one season almost 100,000 deer were killed in Pennsylvania during the open season for shooting them, and an average of more than 20,000 males are taken each year in Pennsylvania alone.

The moose. The moose is chiefly a northern mammal ranging in the United States from Maine to the Rocky Mountains. However, its distribution is rather discontinous, and its range seldom extends below North Dakota. A smaller species inhabits the Yellowstone National Forest and some sections of Montana, Wyoming, and Idaho.

The moose is a stately animal, and it is the largest of the American deer family. Its palmated antlers are huge, and the shoulders are high in comparison with other deer. The young are not spotted like the fawn of the Virginia deer. The cow has only one calf her first year and usually two thereafter. While it is rather ungainly in appearance, there is something majestic about the moose.

The moose feeds upon the stems and roots of aquatic plants in the summer and upon shrubs, grasses, and the lower leaves of trees in fall and winter. Mating takes place in the fall. The bull moose calls for a mate and otherwise reveals his location by breaking brush with wanton abandon. Sometimes the call is answered by a cow, and the two sexes move toward each other with frequent communications. When the call is answered by another male, the moose prepares for combat. Calling takes place only during the mating season.

The elk. The wapiti or elk (*Cervus canadensis*), sometimes called the American stag, is the largest American deer with the exception of the moose. It is a rather rare animal in most sections of its original range, which included the entire northern section of the United States. It is still present in numbers in some northeastern states, notably Pennsylvania, due to restocking.

The habits of the elk are typically those of most other deer, the males being polygamous and resorting to calling during the breeding season. The males engage in bitter combat as do our native deer.

The elk is a dark chestnut brown with grayish sides and a dark

underside. There is a white patch between the hind legs and a straw-colored patch on the rump. The males have widely branched antlers which are deciduous. It feeds on grass, foliage, twigs, and herbaceous plants. It is much larger than the Virginia deer. The enemies of the elk are the bear, wolf, and cougar.

The caribou. The caribou is a large deer with slightly palmated antlers on both sexes. It is also a northern mammal, with several subspecies ranging throughout most of North America north of latitude 45°.

The antelope. The pronghorn antelope is a small ungulate with simple curved antlers on both sexes. The antler carries one lateral prong. It is confined to the plains and the mountainous sections of the Far West.

Fossils

The ardent student of nature engages in field studies; and on his excursions he will inevitably find some evidences of organisms that lived long ago. These evidences may be the preserved footprints of some prehistoric beast or may be skeletons of animals long since passed into extinction. Sometimes the shells, teeth, or even the entire organism itself may be found embedded in the rocks. More frequently, the imprints of leaves and ferns are found in loose shale. These remains are called fossils; they are either the preserved organisms themselves or the molds of the originals which have been formed by petrefaction. In petrifying, the substance of the organism is slowly replaced by earthy material, leaving the perfectly formed part or whole.

Fossils are vastly important in that they reveal the kinds of living things that once inhabited the earth. Through their study the course of evolution was first determined, later to be substantiated by developmental studies of living things.

If the processes of fossilization had not taken place, we would not be fortunate enough to gaze upon the skeletons of giant dinosaurs, mammoths, saber-toothed tigers, ground sloths, and such grotesque creatures as megatherium, archaeopteryx, glyptodon, mastodon, and numerous others.[1] Without fossil remains, the evolution of the horse from a primitive five-toed creature no larger than a dog to its present state could not have been determined. The fossil remains of the camel have made it possible to trace its origin in

[1] See literature appended to this chapter.

America and its subsequent migration to Asia across the continental bridge that once connected North America and the Asiatic continent.

Through fossil remains the primitive ancestors of most of our native plants and animals have become known. Through them also the topographical and climatic conditions which once obtained in regions are indicated. Just as the known artifacts of Indian tribes found in various regions indicate the migrations of nomadic tribes, so too the fossil remains of animals, often fragmentary, suggest the migrations and dissemination of the various kinds from the centers of origin of numerous species.

Even the primitive one-celled animals have left their remains in rocks of an early geological age, and these remains are examined by grinding sections of the rocks to a tissue paper thickness which allows the transmission of sufficient light to make microscopic examinations possible.

The specialization of insects has been determined by comparing body structures and wing venations of modern insects with the fossil remains of primitive types. What a thrill the collector must have experienced when he found fossil remains of dragon flies with a wing spread of almost two feet. What a feeling of compensation Dr. Roy Chapman Andrews must have enjoyed when he found the fossil eggs of dinosaurs that lived millions of years ago. There is real excitement in fossil hunting, and it is accompanied with pleasurable emotions when the remains of plants and animals that lived in prehistoric times are discovered.

And these discoveries can be made in most sections. In the soft coal region many of the boulders along the streams show the imprints of the tropical or subtropical plants such as calamites, lepidodendrons, and sigillarids, which undoubtedly contributed much to the formation of coal. In the slaty shales which are unearthed by coal-mining operations, tree ferns and other beautiful plant remains are often found. In stone quarries, fossil fishes, shelled mollusks, insect fossils, many kinds of leaves, and flowers are frequently found. Limestone shale invariably produces some fossilized remains which are interesting. In excavations for large buildings, the older strata are sometimes revealed; and these are sometimes prolific in fossil remains. In excavating for the Cathedral of Learning at the University of Pittsburgh, for instance, the preglacial gravel which marks the former bed of the

Monongahela River was unearthed. The present river bed is more than a mile from the university.

In the terminal and lateral moraines of the glaciers which once descended into the United States, there are remains of corals and other very ancient animal forms which were transported by the glaciers in their movements from northern sections, where the earlier strata are close to the surface of the ground. The smooth, oval, or rounded nodules which are frequently found embedded in rocks very often have the remains of fishes and other organisms in them; and these can be seen by splitting open these unique formations.

When fossils are found, an effort should be made to determine what they are. When the finder cannot do this, he should submit them to authorities in universities and museums for identification. The fossils may be important contributions to our knowledge of the past, and they should be carefully collected and handled. Extreme care should be taken so as to keep them unbroken when possible.

Not only will fossils indicate what lived in the past, but the student will ofttimes observe some interesting relationships between the ancient remains and living representatives which he can see today. Furthermore, the unvarying law of change will be emphasized. For instance, on the very tops of several western ridges in the Allegheny Mountains there are quarries in which thousands of perfectly formed shells of marine brachiopods can be found. The presence of these fossils of animals, that could not have lived anywhere but in the shallow waters of the ocean, on the highest parts of a mountain chain are testimonials which corroborate the saying that "the old order changeth."

Their presence indicates that their present location once marked the shore line of an ocean which shifted its basin in the ages that followed. The presence of tropical plants such as lepidodendrons and sigillarids, together with the remains of armadillos and ground sloths, in a large section of eastern United States indicates that prior to the descent of the glaciers this region was once warm and humid. The ecology of numerous species, the remains of which are found in this section, has made it possible to substantiate deductions made from the study of these fossil remains. And through these studies, the origin, distribution, and genealogy of plants and animals, and the climatic conditions under which they lived, have been determined. Through them also the subsequent climatic and

topographic changes that have taken place, and the responses of both plants and animals to these changes, are revealed. All of these things contribute much to our concept of evolution; and all of them add greatly to our appreciation of life as it now exists in the sections where we live. Furthermore, the information thus obtained makes possible a deeper, more comprehensive, and more pleasant interpretation of the behavior, the structural makeup, coloration, habitat selectivity, habits, and life histories of the organisms which command the attention of the naturalist and to which this text is devoted.

Therefore a course in nature study should include the study of local fossils and the geological history of the region. The references attached to this chapter will point the way to such studies.

BIBLIOGRAPHY

Mammals

Adams, Charles C., "The Conservation of Predatory Mammals," *Jour. Mammalogy*, Vol. 6, May, 1925, No. 2.

Anthony, H. E., *Field Book of North American Mammals*. Putnam, 1928.

Anthony, H. E., and others, *Mammals of America*. Nature Lovers' Library, Univ. Soc., Inc., 1917.

Bailey, Vernon, *Beaver Habits, Beaver Control, and Possibilities in Beaver Farming*. Bull. 1078, U. S. Dept. Agric., 1922.

——, "Breeding, Feeding, and Other Habits of Meadow Mice," *Jour. Agric. Research*, Vol. XXVII, 1924, No. 8.

——, *Mammals of New Mexico*. U. S. Dept. Agric. Bur. Biol. Survey, North Amer. Fauna 53 (1931).

——, *Cave Life of Kentucky*. Univ. Notre Dame Press, 1933.

Beard, Dan C., *The American Boy's Book of Wild Animals*. Lippincott, 1921.

Beddard, F. E., *The Mammalia*. Cambridge Nat. Hist. Series, Macmillan, 1923.

Brunner, J., *Tracks and Tracking*. Outing Publishing Co., 1912.

Burroughs, John, *Squirrels and Other Fur Bearers*. Houghton Mifflin, 1909.

Clark, A. H., *Animals of Land and Sea*. Van Nostrand, 1925.

Cornish, C. T., *Animals at Work and Play*. Macmillan, 1904.

Cory, C. B., *The Mammals of Illinois and Wisconsin*. Zoöl. Ser. Field Mus. Nat. Hist., Vol. II, 1912.

Crabb, E. D., *A Preliminary Note on the Number of Tines on the Antlers of Virginia White-tailed Deer as Correlated with Age*. Proc. Okla. Acad. Sci., Vol. 2, 1922.

Dice, L. R., "Life Zones and Mammalian Distribution," *Jour. Mammalogy*, Vol. 4, 1923, No. 1.

——, *A Manual of the Recent Wild Mammals of Michigan.* Mich. Handb. Series, 1927, No. 2.

Gabon, H., *Wanderings of Animals.* Cambridge Univ. Press, 1913.

Gask, Lillian, *All about Animals from A to Z.* Crowell, 1927.

Hahn, W. L., *A Review of the Bats of the Genus Hemiderma*, Proc. U. S. Nat. Mus., Vol. XXXII, 1907, pp. 103–118.

——, *Mammals of Indiana.* 33rd Ann. Rep. Dept. Geol. and Nat. Res., 1909.

Harper, Francis, and others, *Habits of Adirondack Mammals.* N. Y. State Mus., Handb. No. 8, 1929.

Hartman, Carl G., "Studies in the Development of the Opossum," *Jour. Morph.*, Vol. 27, 1916.

——, *Breeding Habits, Development, and Birth of the Opossum.* Smithson. Inst. Pub. 2689 (1923).

Hatt, R. T., *The Red Squirrel: Its Life History and Habits.* Roosevelt Wild Life Animals, Vol. 2, No. 1, N. Y. State College of Forestry, 1929.

Herrick, C. L., *The Mammals of Minnesota.* Minn. Geol. and Nat. Hist. Surv. Bull. 7, 1892.

Hollister, N., *A Synopsis of the American Minks*, Proc. U. S. Nat. Mus., Vol. 44, 1913, pp. 471–480.

——, *A Systematic Account of the Prairie Dogs.* Bur. Biol. Survey, North Amer. Fauna 40 (1916).

Hornaday, W. T., *Our Vanishing Wild Life.* Scribner, 1913.

——, *The American Natural History.* Scribner, 1914.

——, *The Minds and Manners of Wild Animals.* Scribner, 1922.

Howell, A. B., *Aquatic Mammals.* C. C. Thomas, 1930.

——, *A Biological Survey of Alabama.* U. S. Dept. Agric. Bur. Biol. Survey, North Amer. Fauna 45 (1921).

Ingersoll, Ernest, *The Life of Animals.* Macmillan, 1906.

——, *Wild Neighbors.* Macmillan, 1922.

Jackson, H. H. T., *A Review of the American Moles.* U. S. Biol. Survey, North Amer. Fauna 38 (1916).

——, *A Taxonomic Review of the American Long-tailed Shrews.* Bur. Biol. Survey, North Amer. Fauna 51 (1928).

Jordan, D. S., *A Manual of the Vertebrates.* World Book Co., 1929.

Kingsley, J. R., *Comparative Anatomy of Vertebrates* (3rd edition). Blakiston, 1935.

Lantz, D. E., *An Economic Study of Field Mice.* U. S. Dept. Agric. Biol. Survey Bull. 31, 1907.

——, *Economic Value of North American Skunks.* U. S. D. A. Farmer's Bull. 587, 1914.

Lydekker, R., *Wild Life of the World.* F. Warne and Co., 1917.
Mannix, D. P., *The Back-yard Zoo.* Coward-McCann, 1934.
Merriam, C. Hart, *Life and Crop Zones of the United States.* Bull. 10, U. S. Dept. Agric. Bur. Biol. Survey, 1898.
Merrill, S., *The Moose Book.* Dutton, 1916.
Miller, G. S., *Key to the Land Mammals of Northeastern North America.* Bull. N. Y. State Mus., Vol. 8, 1900, No. 38.
——, *A List of North American Recent Mammals.* U. S. Nat. Mus. Bull. 128, 1923.
Miller, G. S., and Allen, G. N., *The American Bats of the Genera Myotis and Pizonyx.* U. S. Nat. Mus. Bull. 144, 1928.
Mills, Enos A., *In Beaver World.* Houghton Mifflin, 1913.
——, *Watched by Wild Animals.* Doubleday Page, 1922.
——, *Wild Animal Homesteads.* Doubleday Page, 1923.
Mosely, E. L., *Our Wild Animals* Appleton, 1927.
Nelson, E. W., *Wild Animals of North America.* Nat. Geog. Soc., 1918.
Osborn, H. F., *The Age of Mammals.* Macmillan, 1910.
Osborn, H. F., and Anthony, H. E., "Can We Save the Mammals?" *Nat. Hist. Mag.*, Vol. 22, Sept.-Oct., 1922.
Osgood, W. H., *The White-tailed Deer.* Field Mus. Nat. Hist., 1922, Leaflet No. 1.
Pratt, H. S., *A Manual of the Land and Fresh Water Vertebrates of United States.* Blakiston, 1923.
Rhoades, S. H., *The Mammals of Pennsylvania and New Jersey.* Privately published, Philadelphia, 1903.
Roosevelt, Theodore, et al., *The Deer Family.* Macmillan, 1902.
Scharf, R. F., *The Origin and Distribution of Life in America.* Constable and Co., London, 1911.
Sclater, W. L., and P. L., *The Geography of Mammals.* Kegan Paul Trench, London, 1899.
Scott, W. B., *History of the Land Mammals in the Western Hemisphere.* Macmillan, 1913.
Seton, E. T., *Wild Animals I Have Known.* Scribner, 1900.
——, *Lives of the Hunted.* Scribner, 1901.
——, *Life Histories of North American Animals.* Scribner, 1909.
——, *Wild Animals at Home.* Doubleday Page, 1913.
——, "Value of Moles," *Jour. Mammalogy*, Vol. 4, 1923, No. 1.
——, *Lives of Game Animals*, Vols. 1, 4. Doubleday Page, 1925 to 1928.
Silver, James, "Rodent Enemies of Fruit and Shade Trees," *Jour. Mammalogy*, Vol. 5, 1924, No. 3.
Stone, Witmer, *The Mammals of New Jersey.* N. J. State Mus. Report, 1907, Vol. 7, Part 2.
Stone, W., and Cram, E., *American Animals.* Doubleday Page, 1902.

Stoner, D., *The Rodents of Iowa.* Iowa Geol. Surv., 1918.
Todd, T. W., *Mammalian Dentition.* Mosby Co., 1913.
True, F. W., *The Puma or American Lion.* Rep. U. S. Nat. Mus., 1889.
U. S. Dept. of Agriculture, Bureau of Biol. Survey, North Amer. Fauna: 13, The Bats; 15, The Jumping Mice; 18, The Pocket Mice; 29, The Rabbits; 31, The Wood Rats; 32, The Muskrats; 36, The Harvest Mice; 38, The Moles; 39, Pocket Gophers; 40, Prairie Dogs; 41, Grizzly and Brown Bears; 44, Flying Squirrels.
Vorhies, C. T., and Taylor, W. P., *Life History of the Kangaroo Rat.* U. S. Dept. Agric. Bull. No. 1091 (1922).
Warren, E. R., *The Mammals of Colorado.* Putnam, 1910.
——, *The Beaver: Its Work and Its Ways.* Williams and Wilkins, 1926.
Williams, S. H., "A River Dolphin from Kartabo, British Guiana," *Zoologica*, Vol. III, 1928, No. 4.
——, *The Mammals of Pennsylvania.* Univ. of Pittsburgh Press, 1928.
——, "The Distribution of Foxes in Pennsylvania," *Jour. Mammalogy*, Vol. II, 1930, No. 3.
——, *The Mammalian Fauna of Pennsylvania.* Ann. Carnegie Mus., Vol. 19, 1930, No. 4.
Woodruff, L. L., *Animal Biology.* Macmillan, 1932.
Wright, W. H., *The Grizzly Bear.* Scribner, 1909.

PALAEONTOLOGY

Arber, E. A. N., *The Natural History of Coal.* Cambridge Univ. Press, 1911.
Balfour, John H., *Introduction to a Study of Palaeontological Botany.* A. and C. Black, 1872.
Bassler, R. S., *Shelled Invertebrates of the Past and Present.* Smithson. Scient. Series, Vol. 10, 1932.
Berry, E. W., *Palaeobotany: a Sketch of the Origin and Evolution of Floras.* Smithson. Rept. for 1918, 1920.
——, *Tree Ancestors.* Williams and Wilkins, 1923.
——, *Palaeontology.* McGraw-Hill, 1929.
Bower, F. O., *Primitive Land Plants.* Macmillan, 1935.
Boyle, Cornelius B., *Catalogue and Bibliography of North American Mesozoic Invertebrata.* U. S. Geol. Survey, Vol. 27, 1893, No. 102.
Bradley, John Hodgdon, *Parade of the Living.* Coward-McCann, 1930.
Brooks, C. E. P., *The Evolution of Climate.* Benn Brothers, London, 1922.
Brooks, William Keith, *Origin of Oldest Fossils and Discovery of the Bottom of the Ocean.* Smithson. Inst. Ann. Rept. 1894, Part 1, pp. 359–376.
Chamberlain, C. J., *The Living Cycads.* Univ. of Chicago Press, 1919.
Crabtree, J. H., *Rocks and Fossils and How to Identify Them.* Epworth Press, 1921.

Crookall, R., *Coal Measure Plants.* E. Arnold and Co., London, 1929.
Daly, R. A., *Our Mobile Earth.* Scribner, 1926.
Davies, Arthur M., *Introduction to Palaeontology.* Murby Co., 1920.
Dawson, Sir J. W., *The Geological History of Plants.* Appleton, 1896.
——, *Fossil Plants,* 4 vols. Kegan Paul Trench, London, 1898 to 1914.
Day, Clarence, *Scenes from the Mesozoic.* Yale Univ. Press, 1935.
Dendy, A., *Outlines of Evolutionary Biology.* Appleton, 1912.
Fenton, Caroll Lane, *The World of Fossils.* Appleton, 1933.
Flower, W. H., and Lydekker, R., *An Introduction to the Study of Mammals, Living and Extinct.* A. and C. Black, 1891.
Goldring, Winifred, *Handbook of Palaeontology for Beginners and Amateurs* (in 2 vols.). N. Y. State Mus. Handbook 9–10, 1929 to 1931.
Hawkins, Herbert L., *Invertebrate Palaeontology; an Introduction to the Study of Fossils.* Methuen Co., 1920.
Hollick, Charles A., *Cretaceous Flora of Southern New York and New England.* U. S. Geol. Surv. Monog., Vol. 50, 1906.
Jennings, Otto E., *Fossil Plants from Beds of Volcanic Ash of Western Montana.* Carnegie Inst. Memoirs, Vol. 8, 1920, No. 2.
Kellogg, Remington, *On the Occurrence of Remains of Fossil of the Genus Eurhinodelphis in North America.* Proc. U. S. Nat. Mus., Vol. 66, 1925, Art. 26.
Knipe, Henry R., *Evolution in the Past.* Herbert and Daniel, 1912.
Knowlton, Frank H., *Catalogue to Mesozoic and Cenozoic Plants of North America.* Govt. Printing Office, 1919.
——, *Plants of the Past.* Princeton Univ. Press, 1927.
Lankester, Edwin R., *Extinct Animals.* Henry Holt, 1905.
Lesley, John Peter, *Dictionary of Fossils of Pennsylvania and Neighboring States.* Pa. Geol. Survey (2nd surv.), 1889–18.
Lucas, H. A., *Animals of the Past.* Am. Mus. Nat. Hist. Handbook No. 4, 1929.
Lull, Richard S., *Triassic Life of the Connecticut Valley.* Conn. Geol. and Nat. Hist. Surv. Bull. 24, 1915.
——, *Organic Evolution.* Macmillan, 1929.
Lydekker, L., *The Horse and Its Relatives.* Macmillan, 1912.
Moddie, Roy L., *A Popular Guide to the Nature and Environment of the Fossil Vertebrates of New York.* N. Y. State Mus. Handbook 12, 1933.
Nettleroth, Henry, *Kentucky Fossil Shells; Monograph on Fossil Shells of the Silurian and Devonian Rocks of Kentucky.* Ky. Geol. Survey, 1889.
Newberry, John S., *Fossil Fishes and Fossil Plants of the Triassic Rocks of New Jersey and the Connecticut Valley.* U. S. Geol. Surv. Monog., Vol. 14, 1888.

Newberry, John S., *Later Extinct Floras of North America.* U. S. Geol. Surv. Monog., Vol. 35, 1898.

Osborn, H. F., *The Age of Mammals in Europe, Asia, and North America.* Macmillan, 1910.

——, *The Origin and Evolution of Life.* Scribner, 1917.

Owen, Sir Richard, *Palaeontology; or a Systematic Summary of Extinct Animals and Their Geological Relations.* A. and C. Black, 1861.

Scharff, R. F., *The Origin and Distribution of Life in America.* Constable and Co., 1911.

Schuchert, Charles, *Climates of Geologic Time.* Smithson. Ann. Rep., 1914.

——, *Outlines of Historical Geology.* John Wiley and Sons, 1931.

Scott, Dukinfield H., *The Evolution of Plants.* Henry Holt, 1911.

——, *Studies in Fossil Botany.* I, 1920; II, 1923. A. and C. Black.

——, *Extinct Plants and Problems of Evolution.* Macmillan, 1924.

Scott, W. B., *History of the Land Mammals of the Western Hemisphere.* Macmillan, 1929.

Scudder, Samuel H., *Review of Present Knowledge of Fossil Insects, Including Myriapods and Arachnids.* U. S. Geol. Surv. Bull., Vol. 5, 1886, No. 31.

——, *Tertiary Insects of North America.* U. S. Geol. Surv. Bull., Vol. 10, 1890, No. 69.

——, *Index to Known Fossil Insects of the World Including Myriapods and Arachnids.* U. S. Geol. Surv. Bull., Vol. 10, 1891, No. 71.

——, *Some Insects of Special Interest from Florissant Colorado and Other Points in the Tertiaries of Colorado and Utah.* U. S. Geol. Surv. Bull. No. 93, 1892.

——, *Insect Fauna of a Rhode Island Coal Field.* U. S. Geol. Surv. Bull. 101, 1893.

Seward, A. C., *Fossil Plants,* 4 vols. Cambridge Univ. Press, 1898 to 1919.

——, *Plant Life through the Ages.* Cambridge Univ. Press, 1933.

Shimer, Hervey W., *Introduction to a Study of Fossils.* Macmillan, 1933.

Stephenson, Lloyd W., *Additions to the Upper Cretaceous Invertebrate Faunas of the Carolinas.* Proc. U. S. Nat. Mus., Vol. 72, 1927, Art. 10.

Sternberg, Charles H., *Life of a Fossil Hunter.* Henry Holt, 1909.

Stopes, Marie C., *Ancient Plants.* Blackie and Sons, London, 1910.

Weller, Stuart, *Bibliographical Index of North American Carboniferous Invertebrates.* U. S. Geol. Sur., Vol. 27, 1898, No. 153.

——, *Paleozoic Faunas.* New Jersey Geol. Sur. (3d survey), Rep. on Palaeontology, Vol. 3, 1903.

White, Charles A., *On Mesozoic Fossils.* U. S. Geol. Sur. Bull., Vol. 1, 1884, No. 4.

——, *On the Fresh Water Invertebrates of the North American Jurassic.* U. S. Geol. Sur. Bull., Vol. 4, 1886, No. 29.

White, David, "The Prehistoric Forests of Pennsylvania," *Forest Leaves*, Vol. 19, 1924, p. 169.
Williams, H. S., *Geological Biology*. Henry Holt, 1895.
——, *Contributions to Devonian Palaeontology 1903*. Govt. Printing Office, Washington, 1905.

PART III

PLANT STUDY

CHAPTER XX

THE STUDY OF PLANTS

It has already been indicated that, in the last analysis, the fundamental difference between plants and animals is chiefly in their nutrition. Like the animals, plants show a great diversity of size, form, and structure. They exhibit a wide series of adaptations and adjustments which enable them to survive in all sorts of situations and under a great variety of conditions. Their ecology is just as interesting as the environmental relationships of animals, and among them are to be found some of the most astounding revelations in nature.

Plants are living organisms. They eat—they grow—they reproduce. In addition, they are subject to the laws of heredity, natural selection, and adaptation, as are animals. They must be considered from the standpoint of morphology, physiology, geographical distribution, and response to environmental conditions because they *are* living organisms. Among them are large and small, good and bad, dangerous and beneficial kinds.

Plant Groups

There are four major plant groups, each differing greatly from the others. They are as follows:

1. **The Thallophytes,** which include the algae and fungi, are the lowest in the plant scale. They possess no roots or leaves and they reproduce, usually, by single-celled spores. They are found in moist places, and the group comprises myriads of very distantly related kinds. Among them are the algae; fungi, such as toadstools, mushrooms, bracket fungi; bacteria; molds; mildews; rusts, such as the wheat rust; and blights, such as the chestnut blight and the white pine blister disease. In these plants there is a simplicity of structure marked by a lack of specialized tissues and organs.

Just as in the lower animals there may be found a wide assortment of reproductive processes, so in these lowly plants there may be seen modifications of both sexual and asexual methods.

Most of the water species in this group produce unicellular spores which are quite motile, swimming about by means of cilia or flagella. These are called zoöspores because of their resemblance to animals, and the beginning student might easily mistake these for Protozoans. In plants which live in air, the spores are diverse in form and origin; and they are scattered by winds. In the one-

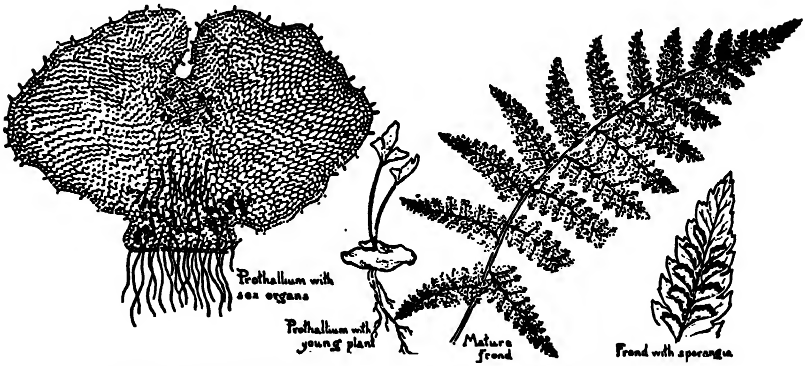


FIG. 212. The life history of the fern. Courtesy General Biol. Supply Co.

celled plants reproduction is sometimes effected by fission, the individual simply dividing into two parts.

In some fungus plants sexual reproduction is accomplished by the conjugation of two similar spores (gametes) to form a zygospore. In others, dissimilar male and female spores or gametes are produced; and these unite to form an oöspore; the union constitutes fertilization.

The phylogenetic history of plants shows a development or evolution from simple ancestral kinds, like the *Thallophytes*, to the highly specialized flowering plants of today.

The algae. There are four main classes of algae, viz., the blue-green, the green, the brown, and the red algae. The great majority of them are aquatic, and the latter two are chiefly marine.

The algae are the only *Thallophytes* which contain chlorophyll and they are therefore able to manufacture their own food. In many of them, the individual plants are microscopic, and therefore they cannot be seen with the naked eye. In the blue-green algae, the chlorophyll seems to be dissolved in the cytoplasm of the cell; but in most of the others, the chlorophyll is usually confined in definite cell structures called chloroplasts or chromato-

phores. The Red Sea is so named because of the countless thousands of red algae which impart a red color to the water. This is a red stage of a blue-green algae (*Trichodesmium*).

The blue-green algae (*Cyanophyceae*) are the simplest and lowliest of all green plants. They are single-celled, but many of them adhere together to form colonies. Reproduction in them is effected by simple division.

The green algae (*Chlorophyceae*) comprise the greatest number of algae. The group includes colonial forms like the volvox [1] and numerous single-celled, swimming individuals. The filamentous algae such as *Cladophora*, which covers stones in running water and which is common in the lakes just off the shore where the breakers begin; *Ulothrix*, which covers stones in cold water; and *Spirogyra*, frog spit or pond scum, are green algae.

The green algae reproduce by the production of zoöspores, zygospores, and oöspores. The common *Chara*, which covers the bottom of protected bays in the Great Lakes and also in fresh-water ponds, probably belongs to the green algae, although antheridia and oögonia, which are rather complicated reproductive processes, are borne along the branches, which are arranged in whorls at definite places along the stem.

The brown algae (*Phaeophyceae*) are the largest and most highly specialized as a rule, although the reproductive processes of the red algae are a little more complex. They include, in addition to many small filamentous kinds, the various seaweeds such as kelp and rockweed. In these, the hollow stems with swollen pockets are adaptations to flotation and hold the plants erect. *Desmids* and *diatoms*, most of which are microscopic and can be found in pond water in great numbers, are unicellular algae of diverse form and color which are of rather uncertain position. Many of these are motile and swim actively about.

The fungi. The fungi are distinguished from the algae by the lack of chlorophyll. These plants are, therefore, unable to manufacture their own food by photosynthesis. Many of them, such as bacteria and molds, are parasitic; while hundreds of species of puff balls, mushrooms, and bracket fungi are saprophytic, living on dead organic matter. The group is extremely diverse and includes the germs of typhoid fever, diphtheria, tuberculosis,

[1] The volvox is still a controversial organism and it is claimed by both botanists and zoölogists.

pneumonia, and other pathogenic forms. In addition to these, there are many edible mushrooms, and other gill fungi included. Some of them, such as certain of the *Amanitas*, or toadstools, are deadly poisonous. To the above list of fungus plants may also be added the stink-horn fungus, the edible morel, corn smut, ringworm, the black knot of plum trees, yeasts, lichens, and slime molds. A number of common edible and poisonous fungi are shown in Plate XXX.

The fungi play an important part in nature, contributing their beneficial services in a myriad of ways—killing harmful insects, serving as food, converting dead wood into utilizable substances in the soil, and converting atmospheric nitrogen into soluble nitrates which nourish other plants. On the other hand, they menace man's existence by producing diseases, destroying his crops, and spoiling his food and clothing. There are thousands of species of fungi, and among them are to be seen a wide variety of reproductive habits which make impossible general statements about their propagation. Every college textbook of botany explains these.

There are six principal groups of fungus plants, viz: (1) *Bacteria*, which are usually microscopic. Many of these are pathogenic. (2) *Myxomycetes*, a controversial group, many of which are difficult to establish as either plants or animals. These are the slimy, irregular, jelly-like masses frequently seen on dead logs in moist woods. The masses are colonies of hundreds of individuals; and the aggregations are capable of slow movement, a slimy trail revealing the migration of the mass. Some of the slime molds are recognized as animals and grouped under the phylum *Mycetozoa*. (3) *Phycomycetes*, which include bread molds, water molds, blights, mildews, and black molds. They are sometimes called the algae-like fungi. (4) *Ascomycetes*, or sac fungi, which include cup fungi, blue molds, knot fungi, and yeasts. (5) *Basidiomycetes*, in which many plant diseases such as smuts and wheat rust (*Puccinia graminis*), and also toadstools and other fleshy gill fungi, mushrooms, puff balls, and stink horns, are grouped. The group is a very large one and it exhibits a great variety of form, size, and structure. Most of them reproduce by spores such as are seen in dry puff balls. The belief that the dust from a puff ball will cause blindness is not justified. Puff balls sometimes attain a diameter of eighteen inches, and most of them are edible when

young. (6) *Lichens*, of which there are many species. Some of them are beautiful in form and color. The lichens grow on the trunks of trees, on dead logs, on stumps, and on stones, often associated with mosses.

2. **The Bryophytes** are the liverworts (*Hepaticae*) and the mosses (*Musci*). They abound in damp places but seldom live in water. They may be distinguished from the Thallophytes by their more highly specialized reproductive structures. As a rule, Bryophytes are small, and most of them lack root structures. The reproductive processes are much more complex, involving in many species an alternation of generations which need not be discussed here.

The *Hepaticae* or liverworts are low-growing creeping plants, the bodies of which are oddly shaped, leaf-like structures (thalli) which lie flat on the ground, the growing parts becoming anchored by thread-like filaments or rhizoids. A number of them are floating forms such as *Ricciocarpus* and *Riccia*, which are found in ponds. These are pictured in most botany texts.

The *Musci* or mosses are chiefly terrestrial, and many of them are erect, although a number of species are recumbent. The leaves are arranged in spirals around the simplified stem. There are no true roots, and the plants are anchored by the filaments or rhizoids.

There are two main orders of mosses known as: (1) the peat or sphagnum mosses (*Sphagnales*), and (2) the true mosses (*Bryales*). Identification of species is extremely difficult, and only fruiting plants are of much value for identification studies.

3. **The Pteridophytes.** There is little or no connection between the mosses and the Pteridophytes, which include the ferns, club mosses, and horsetails. These plants are conspicuous and abundant, and the student of nature will want to identify the various common ferns and to recognize the club mosses and horsetails. The Pteridophytes possess true roots, stems, and leaves, as do the seed-bearing plants. However, instead of reproducing by seeds, the Pteridophytes produce spores like the preceding groups. There are three classes of Pteridophytes, viz: (1) *Filicineae* or ferns; (2) *Lycopodineae*, the club mosses or ground pines; (3) *Equisetineae* or horsetails.

The ferns comprise the largest and most conspicuous plants in the group, and they also constitute the greatest number of species. The leaves of ferns are called fronds; and as a rule, they are deeply cut, giving the appearance of being compound. The stem is short

and it is usually under the ground so that the coiled leaves appear to rise directly from the earth.

The ferns bear no flowers, reproduction being effected by spores which are produced in the sporangia contained in the sori, which consist of brownish spore cases on the undersides of the leaves of fruiting plants. The rusty-colored clusters of spore cases are sometimes mistaken for diseases. Usually the sporangium is surrounded by a ring (the annulus) of cells which is so constructed that when the spores are ripe the ring contracts like a spring, breaking the sporangium and forcibly ejecting the spores. The spores are affected by moisture; and each develops into a small, thin prothallus (Fig. 212) which is almost heart-shaped and which grows flat on the ground, being anchored by hair-like root structures or rhizoids. The sexual organs grow on the underside of the prothallia and are called *archegonia* which develop near the notch, and *antheridia* which grow further back among the rhizoids (Fig. 212). The sperms (which are motile) are produced in the antheridia and fertilize the egg cell in the archegonium. A plant called the sporophyte (Fig. 212) is produced, and this gives rise to the mature fern.

There are many kinds of ferns. The most common species consist of: the sensitive fern, *Onoclea sensibilis;* the bracken, a common Christmas variety; and the rock polypody, *Polypodium vulgare.*.

The club mosses are not all fern-like in appearance. In many of them the leaves are small and closely compacted on the stem, giving them a moss-like appearance. These plants are much smaller than ferns, being not over six inches high. The spore-bearing structures, or sporangia, are borne on the upper surface of the leaf. As a rule, these spore-bearing leaves are tall, stout, and scale-like; and they are grouped together into a clubbed cone or strobilus at the top of a branch, hence their name club mosses.

The horsetails, or scouring rushes, are represented by a single genus *Equisetum.* They are common plants along railroads and cinder banks. In the common field horsetail, two distinct types of plants are to be seen; and to one who is unfamiliar with the fertile and sterile plants, they could easily be mistaken for different kinds. In the fertile plants the leaves are short; and they cling to the stem at their nodes, while the tip of the branch bears

the spore-bearing cone. The sterile plant has a spread of long thread-like leaves at every node, giving the plant a bushy appearance.

4. **The Spermatophytes** or seed-bearers include all of the flowering plants; and of course these are the most spectacular. From the appearance of the common Hepatica, which not infrequently raises its daintily colored flower above the last snow of the spring, until the bloom of the witch hazel late in the fall, there is an interesting succession of flowering plants to attract our attention. Following the Hepatica there comes a host of other spring flowers, including spring beauty (*Claytonia virginica*), dog-tooth violets (*Erythronium americanum,* and *E. albidum*), skunk cabbage (*Symplocarpus foetidus*), Jack-in-the-pulpit (*Arisaema triloba*), trillium, trailing arbutus (*Epigaea repens*), and many others. These are followed by azaleas, dandelions, wood betony, daisies, St. Johnswort, sunflowers, and the usual contingent of summer flowers. As the summer wanes, the goldenrods, joe-pye weeds (*Eupatorium*), and ironweeds (*Vernonia*) come into bloom, with the asters and witch hazel (*Hammamelis*) blooming until late in the fall.

It is in the kingdom of flowering plants that the science of botany had its beginning. In this group, man finds the greater supply of his food, timber, and fibrous materials. Flowers have also played an important rôle in developing the aesthetic qualities of mankind.

As far as vegetative characters are concerned the *Spermatophytes* are rather similar to the *Pteridophytes*. They exhibit a vigorous development of the root, stem, and leaf. The chief character which distinguishes the flowering plants from all others is the production of the seed, thus introducing a vastly different method of reproduction.

There are two classes of seed plants, and these are called *Gymnosperms* and *Angiosperms*. The difference is chiefly the manner in which the ovules are borne. In the *gymnosperms,* or naked seeded plants, the ovules are not encased in an ovary; they are freely exposed to the air. Pines, firs, and ginkos are gymnosperms. The angiosperms have protected seeds or ovules which are enclosed in an ovary. The angiosperms are divided into two clearly differentiated groups known as dicotyledons and monocotyledons. The cotyledon is a seed leaf, such as the halves of a bean; and as

the prefixes di and mono indicate, the differences are merely in the number of cotyledons or seed leaves.

The dicotyledons have, first, a netted venation in the leaf, as opposed to the parallel-veined system typical of monocotyledons; second, the distribution of the vascular system in a ring or tube which separates an internal pith from an outer cortex, while in monocotyledons the vascular system consists of irregularly scattered fibro-vascular bundles such as are to be seen in the cross-section of a corn stalk; third, in the dicotyledons the floral parts (petals, sepals, etc.) usually develop in multiples of four or five, while in monocotyledons these parts generally occur in multiples of three.

The dicotyledons are generally divided into two groups. The first group (*Archichlamydeae*) includes those plants in which the calyx and corolla are either poorly developed or in which the sepals and petals are separated. The second group (*Sympetalae*) includes the flowering plants which have the petals and sepals fused together into a solid, wheel-like or tubular structure as in the morning glory and trumpet flower.

The common orders of dicotyledons include the following, into which numerous plant families are grouped. It is hoped that this brief classification will assist in placing flowering plants into their proper groups.

DICOTYLEDONS (over 100,000 species):

I. In the *Archichlamydeae* the following orders are found:

(1) *Amentiferae* (oak, beech, walnut, chestnut, alder, hickory, birch, willow, poplar). In these the perianth, when present, is scale-like. The flowers are dry and chaffy; and they are frequently arranged in a long, cone-like ament or catkin. They are mostly wind-pollinated.

(2) *Ranales* (buttercup, magnolia, laurel, water lily, tulip tree). In these the stamens and carpels are often numerous instead of being reduced to conform to a definite pattern in their arrangement. They are usually pollinated by insects.

(3) *Rosales* (rose, apple blossom, cherry, peach, saxifrage, locust, wild pea, and a host of others with conspicuous flowers, together with many vegetables). In this group we find many conspicuous flowers which are rather regular as a rule. In the legumes, however, irregular, highly specialized, butterfly-like, papilionaceous flowers develop.

(4) *Umbellales* (dog woods [shrubs], wild carrot [herbs]). In these the flowers are usually small and arranged in compact flat-topped clusters

called umbels. Such flowers mark the highest development among the *Archichlamydeae.*

II. In the *Sympetalae*, the most important orders are:

(1) *Ericales* (laurel, blueberry, heath—mostly shrubby). The flowers of these are intermediate between the *Archichlamydeae* and the *Sympetalae.*

(2) *Tubiflorales* (phlox, morning glory, verbena, nightshade, potato, tomato, trumpet flower). These are mostly herbaceous, and the corollas are conspicuously disc-like to tubular. The corollas are regular in lower families but quite irregular in the higher ones.

(3) *Rubiales* (honeysuckle, madder, buttonbush). In this group the flowers occur in compact clusters, and they are constructed on the plan of five or four.

(4) *Campanulales* (dandelion and all other composites, bellwort, and gourd families). Of these the composites are most numerous. The flowers are arranged in complex heads which resemble a single flower. The flowers near the margin are often different from those at the center of the head. The calyx is reduced and becomes a scale-like pappus surmounting a single-seeded ovary in the composites. All of these are herbaceous.

MONOCOTYLEDONS (over 30,000 species):

(1) *Glumales* (grasses, sedges, cereal grains). In these the small, inconspicuous flowers lack a typical calyx and corolla; and they are arranged in clusters. They are mostly wind-pollinated.

(2) *Palmales* (palms). The flowers are small and borne in spikes.

(3) *Arales* (Jack-in-the-pulpit, skunk cabbage). The leaves of these are atypically net-veined. The flowers usually lack a perianth, although the skunk cabbage has 4 sepals. They are small and clustered on a spadix, which is enveloped by a large and often brilliantly colored bract called the spathe.

(4) *Liliales* (lily, iris, amaryllis, dog-tooth violet). These have well-developed bulbs or root stalks. The perianth is very conspicuous.

(5) *Orchidales* (lady's slipper, fringed orchids). These are characterized by their irregularity of form and their spectacular adaptations for insect visitation. These and the composites mark the highest development of plants.

Edible and medicinal plants. An interesting and utilitarian study of native plants is the classification of them into such categories as edible, medicinal, poisonous, and noxious.

The person is to be pitied who has spent years tramping through the woods and fields without having enjoyed many common plants that have edible parts. It is especially valuable to know which plants are poisonous to eat or touch and which ones have

irritating thorns, hairs, or juices. To chew birch bark or slippery elm, and to munch such delicacies as sour grass (*Oxalis*), water cress, mountain tea leaves and berries, wild grapes, huckleberries, Pennyroyal leaves, sassafras root, service berries, dew berries, wild gooseberries, blackberries, wild strawberries, ripe persimmons, wild cherries, beechnuts, and the host of other tid-bits to be found in almost every section of the country, makes the walk through the woods so much more enjoyable.

Then, too, it is sometimes worth while to know what plants can be eaten when cooked or otherwise prepared. Dandelion greens, young shoots of the pokeweed, chokecherries, bracket fungi, mushrooms, puff balls, and numerous others, dependent upon the geography of the section, are worth knowing about.

In every section of the world where plants grow, there are many which have been used for ages to cure the ills of the populace. Long before the dawn of modern medicine, there were individuals who learned the therapeutic values of plants, and these members of the tribes assumed the responsibility of ministering to the ills of their fellows. Such individuals still exist among primitive peoples, and they are known as medicine men. They treat everything from snake bite and a broken leg to the toothache and insanity.

Their methods are crude, and in many ways they are ludicrous; and yet they have been important factors in the survival of primitive races. Through them we have learned to know many drugs which have contributed much to our own comfort and security. Quinine is one of the greatest drugs ever discovered, but it was used by Indians long before we ever heard of it. The history of quinine is worth knowing.

In Dutch Guiana the black Djuka tribes who have descended from African slaves have developed a remarkable knowledge of the therapeutic values of the plants in the New World. While their preparations are crude, they are effective in many cases. It was interesting to note that the Djukas had even discovered an extraction which kept the ticks and mites off their dogs. And although their dogs were as pink as newborn babes, they were comparatively free from annoying parasites.

The *United States Pharmacopeia* is the druggists' handbook. In it are the names of all plants used in medicine. The work is a gigantic one, and it is too general and large for student use. How-

ever, after the local plants have been studied, they can be checked for their medicinal uses. The interesting possibility of such a study should not be overlooked. Many of the plants you see in your own district have names which physicians write on their prescriptions. Among them are ginseng, lobelia, golden seal (*Hydrastis*), boneset (*Eupatorium*), peppermint (*Mentha*), blood root (*Sanguinaria*), wild ginger (*Asarum*), wild geranium (*Geranium*), May apple (*Podophyllum*), soapwort (*Saponaria*), valerian, camomile (*Anthemis*), arnica, anise (*Osmorhiza*), bugbane (*Cimicifuga*). These and many others are described and discussed in the pertinent literature included in the bibliography attached to this chapter.

The Parts of Plants and Their Functions

The roots. The root of a plant is one of its principal vegetative structures, contributing to its existence in a variety of ways. While the real and vital value of root structures is to extract dissolved mineral foodstuffs and moisture from the soil, the root also serves to guy the plant and hold it erect against wind and other forces.

There are also nitrogen-fixing bacteria which cause certain roots to produce root tubercles in which the processes of nitrification are effected. From an agricultural standpoint this is most important since the nitrogen salts (nitrates) are essential to the welfare of all ordinary plants; and these salts are among the chief constituents of commercial fertilizers. Plants such as cow peas and soy beans are planted by farmers and then plowed under when the plants are mature, so as to enrich the nitrogen content of the soil.

There are several kinds of roots, such as the fibrous roots of grasses and corn, and the tap roots of dandelions, radishes, parsnips, and turnips. In the latter kind, the descending main root is the principal stalk or primary root of the plant. In most plants, however, there are lateral branches which are in turn branched. These branches constitute the secondary root system. Frequently the primary root ceases to be the thickest and most conspicuous root stalk, and it is lost in the deliquescence of branches.

In plants having conspicuous primary tap roots, such as the radish, the portion of the plant above the ground is low. In plants having a much branched root system, such as shrubs and trees,

the stem rises to considerable height above the ground; and lateral branches of the root are necessary to give the needed rigid support and also to increase the area from which to draw foodstuffs and moisture.

While it is generally true that the various root systems need certain favorable soil conditions for growth, and that soil determines the situations in which certain plants are found, it is also evident among plants in general that the limits of adjustment in roots are flexible; and any root system will be modified in response to changing conditions. For instance, a root will grow deeper in dry soil or it will grow toward the source of water. The number of root branches may increase in poor soil. In fact, the root may grow to such an extent in poor soil that the parts of the plant above the ground will suffer.

While roots are typically subterranean, they are sometimes produced along the stem high above the ground, as in climbing plants, to add support, or on epiphytes to take nourishment from their hosts. Occasionally these roots penetrate the tissues of their hosts and kill them. In some of these epiphytic plants, aerial roots are produced; and these are capable of extracting nutrient matter from the atmosphere by means of a spongy envelope which holds the moisture.

Along tropical rivers on which tides from the ocean produce a rise and fall of the water level, or in places where there is a seasonal variation of the water level, many of the plants which grow in the water develop roots high on the stem; and these extend into the water when the surface level of the water drops considerably.

The leaves of some plants are capable of producing roots; and many house plants (*begonia*, *geranium*, and *coleus*) can be propagated by simply planting sections of leaves. The migration of the walking fern (*Camptosorus rhizophyllus*) is effected by roots which develop at the tips of mature leaves which bend and touch the ground. Not all plants can develop adventitious roots, however. The twigs of willows and poplars will grow roots when placed in water, but the ability is not possessed by such plants as the oaks, hickories, and ashes.

While the root serves the plant in the above capacities, it must also be borne in mind that the root is the winter storehouse for the sap of the plant. The liquid content of the plant would freeze in the frigid temperatures of northern winters and the expansion

of frozen fluids would completely destroy the tissues. As winter approaches, there is a transpiration of excess moisture, and the concentrated sap descends to the roots which are frequently below the frost line. The reader is referred to botany textbooks for the details of root structure.

The root exhibits many interesting adaptive features beyond those already described. In many plants the stem dies to the ground each year (perennials), but the root remains alive and sends a new stem up the following year. In others the whole plant dies (annuals), and the following year's plants are propagated by seeds.

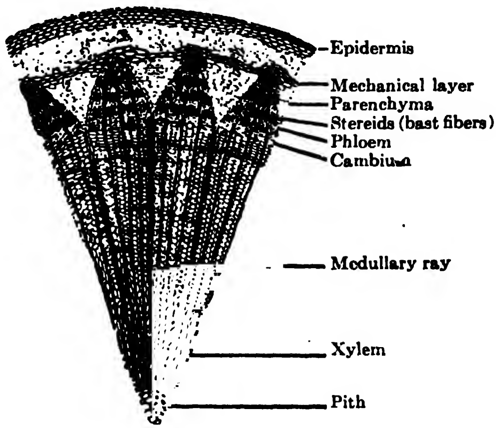


FIG. 213. Cross section of a stem showing regions. Courtesy Gen. Biol. Supply Co.

An eastern plant, commonly called the buffalo nut parasite (*Pyrularia pubera*), has some underground root growths that extend into the roots of nearby plants and parasitically secure additional nutriment. In the common skunk cabbage (*Symplocarpus foetidus*) which lives in soft, spongy, muddy soil where it is difficult to secure anchorage, and where the gaseous content of the soil has a tendency to push the plant out of the ground, certain roots crinkle up; and by this shrinkage the rest of the plant is drawn into the soil.

The function of the stem. The stem is one of the most conspicuous parts of many plants. In woody plants it is usually the largest part. The stem serves to connect the roots and the leaves; and it holds the latter, with the flowers and fruit, up to the sun and in such a position as to attract pollinators and seed distributors. In addition, the stem conducts water and mineral foodstuffs, taken in by the roots, to the upper parts of the plant, and it returns the food manufactured in the leaves to the lower parts of the plant where it is used or stored.

The stem is often highly modified; and it exhibits a wide variation in size, shape, and structure according to the kind of plant.

In the herbaceous plants it is usually soft in texture and dies back to the roots each year. In the shrubs and trees the stems are woody, while in such plants as the corn (monocotyledon) the stem is quite pithy. While the stem is usually erect, there are many plants in which it is recumbent or prostrate (twin flower), lying on the ground. In some plants the stem is horizontal underground (rhizome) as in Solomon's seal. In other plants, such as the dandelion, the stem is almost wanting. The bulbs of the onion and hyacinth are really stems and the potato is a stem (tuber) in which foodstuffs are stored. The sweet potato is a root.

In many plants such as the ivy, morning glory, bindweed, dodder, and the tropical lianas, the stem is very much elongated and adapted to climbing. In these plants tendrils and other climbing structures are produced along the stem. Not infrequently roots are adventitiously produced along the stems of climbing plants.

In water plants the stems are soft and weak due to a lack of woody tissues. In these the stems are frequently hollow; and sometimes, as in seaweeds, they have swollen sacs which give them buoyancy.

The stem shows remarkable adaptive features. One of the most interesting modifications is to be seen in the common water celery or eel grass (*Vallesneria spiralis*). In this plant, which grows completely submerged in large ponds and in lakes, the stem is variable in length, according to the depth. When ready to bloom, the dainty, pistillate flower is just above the surface of the water and exposed to the air. In order to keep the flower above the water level, the stem is coiled like a spring for part of its length, so as to allow for contraction and expansion. In this way the flower is adjusted to changes in the water level.

In desert plants the stems are adapted to the retention of water, while in the stems of some plants such as skunk cabbage reserves of foodstuffs are stored. These excesses of nutriment are used during unfavorable periods. In numerous cases, the stem bears thorns, hairs, or spines in order to protect the plant from the activities of herbivorous animals, and also to prevent crawling insects from ascending to the flowers. In the wild pink or bladder campion (*Silene cucubalus*) each branch of the stem which bears flowers has a ring of sticky substance secreted by the stem, beyond which crawling insects cannot pass. The crawling insects

are usually smooth-bodied, and they therefore cannot carry pollen. Consequently they return no service to the plant for the nectar they steal.

The rise of water in stems is due to capillarity, root pressure, the upward pull caused by the concentration of sap in the leaf cells aided by the transpiration of water from the leaves, and by the pull made possible by the cohesive properties of water.

Further details of stem structure are discussed in the treatise on climbing plants.

The functions of leaves. Like the roots, the leaves are vegetative organs; and in them essential foodstuffs are manufactured. By the aid of light and the green chlorophyll, photosynthesis is effected. Carbon dioxide (CO_2) and water (H_2O) are combined into organic compounds such as glucose or grape sugar and starch ($C_6H_{12}O_6$), which are the basic substances on which animal life is absolutely dependent, either directly or indirectly. Free oxygen is liberated in the process, as the following chemical reaction indicates: $6\ CO_2 + 6\ H_2O \rightarrow C_6H_{12}O_6 + 6\ O_2$.

In addition to the metabolic processes involved in photosynthesis, the leaf is the center of transpiration; and from it water is discharged, although other organs function in this manner also. It is said that a good-sized tree may transpire 2000 pounds of water on a hot summer day. The evaporation of water is effected through the pores or stomata on the back of the leaf. The openings of these pores are regulated by guard cells which respond to the humidity of the surrounding air. The process of transpiration is probably to keep constant the upward flow of sap, and in wooded areas it is a factor in temperature regulation.

The amount of water vapor given off by a plant depends upon several factors. In the tropics where there is considerable rainfall, the leaves are frequently very broad, offering a large area from which to discharge moisture. A Caladium or "elephant ear," with its thousands of stomata, must transpire considerable moisture. In temperate zones where the rainfall is less the leaves are not so large, while in desert regions where water is scarce and where plants must hold their moisture, the leaves are reduced to stem-like structures so as to decrease the area from which water vapor can escape. In some plants such as the stonecrop (*Sedum ternatum*) and numerous cacti, the water is stored in the leaf.

In addition to photosynthesis and the transpiration of water

vapor the leaf is also the structure through which considerable of the respiration takes place. It has already been suggested that respiration in plants is similar to the same process in animals, in which oxygen is taken into the body where it acts upon the carbohydrates, producing carbon dioxide. Oxygen is taken in through the stomata on the leaves as well as through the lenticels. Through the same structures carbon dioxide is discharged. However, photosynthesis takes place only during the hours of daylight while respiration takes place at all times. Therefore no oxygen is liberated during the night while carbon dioxide is being released. For this reason you have probably heard that it is advisable to remove plants from a sickroom at night. In some plants, leaves bear distinct glands (*Ailanthus glandulosa*), but these are not concerned in respiration, as some people believe.

Leaves respond to light intensities and some of them turn their edges toward the strong rays of the midday sun in order to reduce the area exposed to the heat rays. This reduces the amount of water transpired and prevents the loss of too much moisture. Leaf movement is still somewhat of a mystery and recent researches indicate that internal structures called *pulvini* contribute to its effect. A pulvinus is the swollen base of the petiole in leguminous plants.

As has been stated before, the green of leaves is due to the presence of an extremely complex substance called chlorophyll. In the fall when the food substances are withdrawn from the leaves the sap descends to the roots; the leaves die, and the chlorophyll disintegrates. The color of autumn foliage is dominantly yellow with its complements, although red and other pigments are revealed when the chlorophyll is broken up. Analysis shows that chlorophyll contains a mixture of pigments chlorophyll *a* and chlorophyll *b*, both of which are chemically complex. In addition to chlorophyll there are other pigments present; these are mainly xanthophyll and carotin, both yellow pigments, and cyanophyll, a blue pigment. Cyanophyll is dissolved sap color. The mixture of blue and yellow produces green. The leaf color can be obtained by placing crushed leaves in warm alcohol. When a light oil such as benzene, pure gasoline, or xylene is added to extracted leaf color (which is chiefly chlorophyll), under proper conditions, it breaks up into blue and yellow. However, the other pigments are present in varying quantities according to the species

of plant; and the *constituency* of the leaf color determines the coloration of autumn leaves. Sumac, which turns to a scarlet in the fall, contains an abundance of a red pigment called anthocyanin which is also dissolved in the sap. Both cyanophyll and anthocyanin are affected by the chemical nature of the soil. In an acid medium, cyanophyll is blue and anthocyanin is red. When an alkaline condition is produced, cyanophyll turns red and

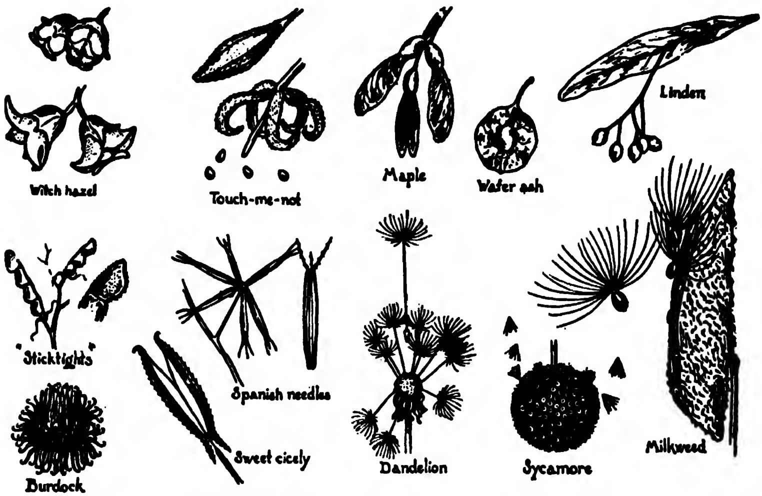


FIG. 214. Seed dispersal. Courtesy Gen. Biol. Supply Co.

anthocyanin becomes blue. The acidity or alkalinity implied is largely a matter of internal metabolic processes in the plants themselves, however, although certain metallic substances in the soil may alter the coloration of flowers. For instance, aluminum is known to affect the color of *Hydrangea*. A pink hydrangea will bear blue flowers if a soluble aluminum compound (alum) is planted in the soil. The coloration of autumn foliage is therefore a matter of chlorophyll decomposition which reveals the pigments present, and not the direct effect of frost, as many people suppose.

Leaves assume many shapes in the various plants. They may be sharp and needle-like, as in pines and spruces; scale-like as in arbor-vitae, or they may be broad and flat as in most plants. The margin or edge may be smooth or entire (laurel), wavy (oak), singly toothed (linden), doubly toothed (elm), or deeply indented to form lobes (maple). They may be simple (oak, elm) or com-

pound (buckeye, locust), and they may be persistent or deciduous. The types of leaves are shown in the chapter on trees. In evergreens, the leaves are not all shed simultaneously in the fall; but most of them cling to the plant during all seasons and are shed singly. In deciduous plants such as most maples, all the leaves drop off when the plant prepares for winter.

Leaves are always arranged in a mosaic so as to allow the sunlight to reach all of them more uniformly. They also exhibit many curious modifications which will be discussed under plant adaptations.

Flowers. Most persons pay attention only to the plants that bear flowers and to these only while they are blooming. What is more, only the conspicuously colored and fragrant flowering plants receive much attention, as a rule.

Flowers are the highly specialized reproductive structures of many plants and they exhibit spectacular modifications for achieving their purpose. Since many flowers depend upon agents of one kind or another for receiving and transferring pollen, the characters of them are extremely variable. Those flowers which depend upon wind and water for cross-pollination are usually inconspicuous and often pass notice. The flowers that depend upon crawling insects are also more or less inconspicuous because they are close to the ground and often concealed between the axils of leaves or hidden by grasses and other plants. But among those flowers which rely upon some active flying visitor to carry pollen from one plant to another, we find the brilliantly colored and highly odorous flowers which usually grow in very prominent places.

In the latter group there are remarkable devices for attracting welcome visitors and for excluding unwelcome ones, and there is also a unique assortment of structural methods of insuring that the flower profits by the visit.

To fully appreciate the numerous adaptive features of flowers it is necessary to become familiar with certain details of floral structure. The flower is composed of the following parts (Fig. 215): (1) The *stalk* or *peduncle* which bears all of the other structures and which is enlarged at the apical end into a hollow receptacle. The body of the flower rests in the receptacle. (2) The *calyx* consists of green floral leaves or sepals which surround the corolla and which may or may not be fused together to form a

cup. (3) The *corolla,* within the calyx, consisting of foliaceous structures called *petals* which are frequently brilliantly colored and usually fragrant. The number of petals is usually the same as the number of sepals. The petals, too, may be fused together to form a tubular corolla, although they are usually separated. (4) The *stamens,* which are the pollen-bearing structures, consist of a slender stalk or *filament* which supports the pollen-bearing *anther* located at the extremity of the filament. The stamens are usually separate and arranged in a circle as are the sepals and petals. Occasionally the stamens are partially fused together either at the filaments or at the anthers. (5) *Pistils* which bear the seeds and in which fertilization takes place. The pistil consists of an *ovary* which, when ripened, is the fruit of the plant. In it are the seeds which are sometimes naked and sometimes enclosed (gymnosperms and angiosperms). In addition to the ovary the pistil has a slender *style* which connects the ovary with the stigma located at the top of the pistil. The *stigma* is usually roughened and sticky. It receives the pollen grains which adhere to it, and the moist stigmatic secretions surround the pollen grains and nourish them until the grains extend long tubes down through the style to the ovary where they fertilize the ovules or seeds. The pollen tubes enter the seeds through the tiny openings or micropyles. The ovules are attached to the ovary by thread-like placentae. The process is more complex than indicated here, involving tube cells and generative cells in the pollen grains, and complex fertilization that is truly sexual. The stamens may be likened to male reproductive organs and the pistils to female organs. The production of the pollen tube may be observed by sprinkling some pollen on the surface of sugar water or diluted molasses in a glass or test tube.

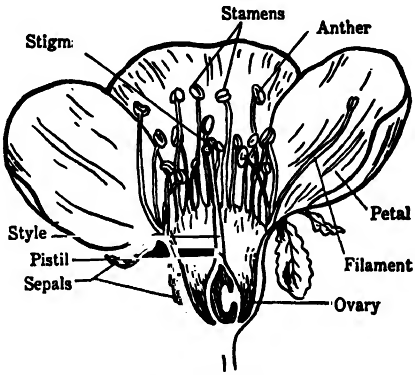


FIG. 215. The parts of a flower. Courtesy Gen. Biol. Supply Co.

The flower does not always possess a corolla and a calyx. When one is absent, it is usually the corolla; and in such cases the calyx

often assumes brilliant colors. Some flowers have both pistils and stamens. Others possess only one set of reproductive structures, and they are therefore either pistillate or staminate. Some plants bear both pistillate and staminate flowers (monoecious), while in other species only one type of flower is produced on an individual plant (dioecious).

There are many kinds of flowers. Some of them occur singly while others are borne in clusters of various shapes and construction. The arrangement of flowers on the plant is known as inflorescence. The solitary flowers may occur singly on stems rising directly from the ground, or they may be borne in the axil between two leaves. The clusters usually include flowers which are reduced in size, while solitary flowers are frequently large.

The kinds of clusters are important (Plates XXXI, XXXII), and a knowledge of them assists greatly in identifying plants. There are six common types of flower clusters; viz: (1) the *raceme* in which the inflorescence has a long axis and the individual flowers are each borne on a stalk of uniform length, as in the hyacinth and lily of the valley; (2) the *spike* which is similar to the *raceme* except that the flowers are seated on the stem and lack the pedicels, as in the hollyhock and plantain; (3) the *corymb* which is a flat-topped cluster produced by pedicels of unequal length attached to a fairly long axis, as in the yarrow and candytuft; (4) the *head* in which the axis is short, with the individual flowers sessile, producing a roundish cluster, such as the buttonbush, sycamore, dandelion, and clover; (5) the *panicle* which is a compound *raceme* and is characteristic of many grasses; (6) the *umbel* in which the axis is short and the individual flowers are borne on pedicels of equal length producing the well-known cluster of wild carrot or Queen Anne's lace. There are several modifications of these typical clusters. Inflorescence is the manner in which flowers bloom. There are two principal types of inflorescence. When the first flowers to open are those on the inside of a cluster or at the tip, the inflorescence is determinate. The reverse, or the blooming of the outer or lower flower first, constitutes indeterminate inflorescence. The wild carrot and the hollyhock illustrate the latter.

Bright colors and distinct odors have been developed to catch the attention of flying insects, and nectar glands are present to induce an intimate visit. Sometimes the petals have stripes on

Milkweed (*Asclepias incarnata*)

Butter and Eggs or Toadflax (*Linaria vulgaris*)

Teasel or Card Teasel (*Dypsacus silvestris*)

Poison Ivy (*Rhus toxicodendron*)

Crane's Bill or Wild Geranium (*Geranium maculatum*)

Oxeye Daisy (*Chrysanthemum leucanthemum*)

Early Goldenrod (*Solidago juncea*)

Yarrow or Milfoil (*Achillea millefolia*)

PLATE XXVII. Common wild flowers and plants. Courtesy Dr. E. M. Gress.

them which serve as guide lines to direct the visitor to the nectar glands. These glands are always strategically located at the base of the flower so that in order to reach them the insect must force its way past the pollen-bearing anthers and the sticky stigma of the pistil. Flying insects are usually hairy-bodied and the grains of pollen adhere to their legs and bodies when they leave the flower. In reaching the nectar glands of another flower, the insect brushes past the stigma of the ovary; and some of the pollen grains rub off and adhere to the stigma, thus effecting cross-fertilization. The anthers or pollen boxes are diverse. Some of them split open lengthwise when the pollen is ripe; and as a rule the anther is loosely borne so that at the slightest disturbance the pollen shakes out. Thus as an insect pushes past the anther it discharges pollen upon it. The openings of the anthers may consist of valves which open like a trapdoor when the pollen is ripe. In many plants the pollen completely covers the anther. The pollen does not always occur in the form of a powder, however. In the milkweed it is borne in small, flattened, angular clips called pollinia (Fig. 218). The angles of the pollen clips extend upward; and as the insects crawl about over the flowers, the claws get caught in the clips. The insect jerks its leg, and the clip of pollen pulls out and dangles from the foot. Insects captured in fields where the milkweed is in bloom almost invariably have the pollen clips on their feet. When the insect alights on another flower, the clip drops off; thus cross-fertilization is effected. Strangely enough, some insects such as the large blue bottle flies and a few native butterflies get caught and are held prisoners until they die. This is due to the fact that the milkweed is not a native American plant, having been imported from Europe or Asia; and native insects, being unfamiliar (?) with its method of pollination, get their feet caught and cannot extricate themselves. There is nothing purposive in this method of entrapping insects by the plant. In fact, when the insect gets caught it defeats the purpose of the plant because the pollen cannot then be transported to another plant.

While many flowers can be pollinated by a number of insects, there is often a specific relationship between the flower and a particular kind of insect, such as between the bumble bee and red clover, and between some flowers with deep corollas and moths with long, sucking tubes. It has already been suggested that one

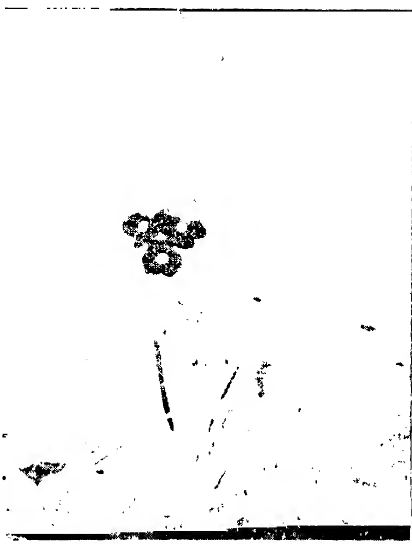
of the most highly specialized relations between an insect and a flower is that of the pronuba moth and the yucca plant. A little, white, tineid moth, *Pronuba yuccasella,* scrapes pollen from the anther and shapes it into a pellet with the front legs. The pellet is carried to the stigma where the female inserts a long, flexible ovipositor into the ovary and lays a long, slender egg beside several of the ovules. After laying the egg, she ascends the pistil and thrusts pollen into the tube of the stigma and packs it in firmly. The ovules develop into seeds, some of which are consumed by

A. B.

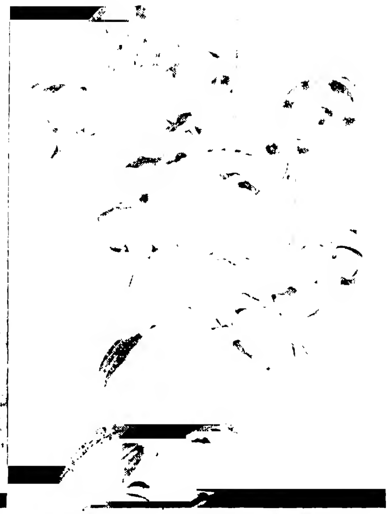
FIG. 216. Two American plants that capture insects. A. Sundew; B. Venus' Flytrap. Courtesy Gen. Biol. Supply Co.

the larva which hatches from the egg. When the moth is not present, the yucca does not produce seeds. The exact purpose of this relationship is not known since the moth itself does not feed and therefore derives no benefit from the flower. Both the plant and the insect have become highly modified for this apparent absolute interdependence.

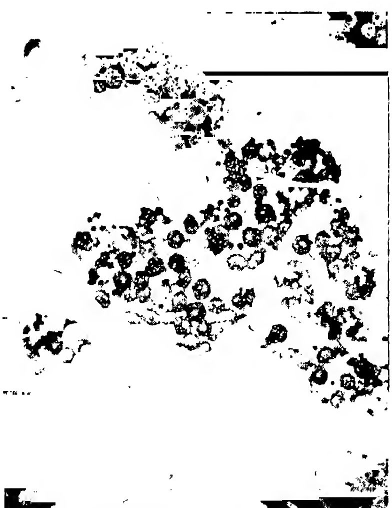
In the iris or blue flag, the drooping sepals form a passageway to the nectar glands (Fig. 219). Above the entrance to the flower and pointing outward is the stigma which resembles a movable lip. As the bee enters, it touches this projecting stigma which bends downward and scrapes pollen from the back of the insect and then springs back in place. The long overhanging anther bends downward as the bee enters; and the hairy back of the bee scrapes pollen from the anther when it backs out of the flower.



Arrowhead (*Sagittaria latifolium*)



Turk's Cap Lily (*Lilium superbum*)



Laurel (*Kalmia latifolia*)

Chicory (*Chicorium intybus*)

PLATE XXVIII. Common wild flowers. Courtesy Dr. E. M. Gress.

Some plants increase the certainty of pollen distribution by having mechanical devices of various sorts. In the barberry the stamens are spread, and they lie with the anthers resting on the petals. The pistil is the most convenient landing spot; and when an insect alights on the flower and inserts its proboscis into the nectar glands, the stamens spontaneously fold over it making it necessary for the visitor to push its way out through an entanglement of powdery anthers.

In mountain laurel, *Kalmia,* there are little, colored pockets in the corolla. Within these pockets the anthers are held until an insect enters the flower. The disturbance caused by the visitor releases the anthers, and the spring-like filament violently snaps upward and showers the insect with pollen.

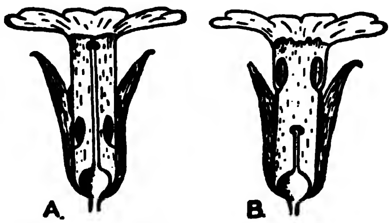


FIG. 217. Dimorphic flowers of Chinese primrose. A. Flower with long style and with stamens attached low in the tube of the corolla; B. Flower with short style and with stamens in the throat of the corolla. From Sinnott, *Botany,* courtesy McGraw-Hill Book Co.

Cross-fertilization seems to be vitally necessary, and flowers have developed diverse ways to prevent self-fertilization. In some of them only pistils or stamens are present. In those flowers where both pistils and stamens are present, they are either arranged so that the pollen from the stamens cannot be transferred to or fall upon the stigma, or the pistils and stamens mature at different times. This latter method is much the more common and effective because when the stamens are ripe, the pistil has not developed sufficiently to receive the pollen; while in other flowers of the same species the ripening process is reversed so that the stigma can receive pollen from another flower when the stamens of the same flower have not sufficiently developed.

In many cases dimorphic flowers are produced. In these plants two kinds of flowers are present; and they are constructed so that the points where the anther and stigma touch the body of the insect are reversed, with the result that the pollen of one is likely to reach the stigma of the other (Fig. 217).

In addition to providing for the certain transference and reception of pollen carried by insect visitors, flowers provide conveniences which make the visit of the insect more comfortable. In

the *papilionaceous* flowers such as snapdragons and legumes, the lower lip is extended to provide a convenient landing place. The colors, odors, and nectar glands also attract unwelcome visitors which render no service to the flower. To exclude these, there are many devices which effectively prevent their entrance. Most of the unwelcome visitors are crawling insects such as ants. These are, as a rule, smooth-bodied, since projecting hairs on their bodies would impede their progress among the grasses and débris on the ground. Pollen will not adhere to the smooth-bodied insects; and hence their visit to the flower would not result in any benefit to the plant, since they would effect no cross-pollination. In order to keep out these smooth-bodied robbers whose presence is undesirable, the flowers are sometimes borne so loosely on the peduncle that when the insect reaches the flower, it drops or sways and the insect cannot mount it. Hairs on the stem, bracts, and other devices which have already been mentioned also help to keep crawling insects from ascending the plant. In papilionaceous flowers there is usually a tuft of hairs in the throat of the corolla which serve as an effective barrier and beyond which the crawling insect cannot pass.

It has been suggested that some plants depend upon the winds for disseminating pollen. The flowers of these plants usually lack the attractive features characteristic of insect-pollinated plants. The corn grows to a remarkable height in a short time, rising above all other annuals in order to raise its tassel-like flower to an elevation where it is exposed to the breezes upon which it depends to scatter its pollen. Because the wind is necessary, it is imperative that the plant rise above its fellows; and as a result the corn grows higher in a single season than any other annual. Its rapid growth is made possible by the endogenous character of its stem. Grasses and cereals likewise grow in huge masses where the wind-carried pollen can be distributed among them. Their flowers are also inconspicuous.

Night-blooming flowers usually depend upon night-flying insects for effecting cross-fertilization. These flowers are, as a rule, white or light yellow so as to be easily visible in the darkness, and they generally have fragrant odors. Many of them remain closed during the day, and some of them shed their fragrance only after the sun sets.

It is advantageous to keep the ripened pollen dry; for when it

becomes wet the grains adhere together in a sticky mass. To provide against such conditions most flowers drop their heads during a rain and raise them again when the sun comes out. Many of them, such as thistles, fold their petals over the pollen during rains to keep it dry. The poor man's weather glass and numerous others are affected by humidity and they simply close up before it rains. The day-blooming flowers either droop or close at night so that the settling dew will not wet the pollen.

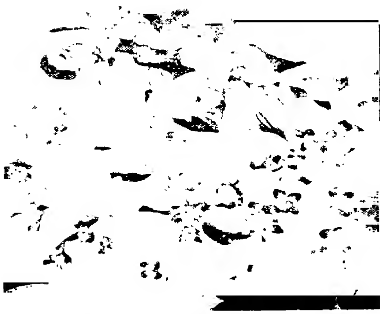
A knowledge of flower structure, combined with the principles involved in bright coloration and insect visitation, make it possible for the observer to "read the palm" and gaze into the inner secrets of flowers in such a way that the philosophy of nature can be pretty well understood.

Adaptations in Plants

Protective devices in plants. Since plants are usually sessile organisms and remain fixed in one place, they must be equipped to withstand all sorts of hardships and to protect themselves from many destructive agents. Some plants, such as trees and shrubs, must endure wider variations of environmental conditions than do animals. Some animals can hibernate for long unfavorable periods. Others construct warm, cozy nests in which they can take refuge from storms, cold, or intense heat. Some species can burrow below the frost line in the ground in frigid weather; and most desert animals burrow or seek the shelter of a plant when the sun's rays become too intense. The birds and a few other animals migrate to more favorable localities in times of stress. But the plant can do none of these. No matter what the conditions are, it remains immobile and must take what comes or perish.

Myriads of animals devour all or parts of plants; and in order to survive the many dangers to which they are exposed plants have developed a host of protective devices which contribute to their safety.

Sometimes the leaves and stem are covered with fine hairs which not only reduce the evaporation of water but which also serve to prevent their being eaten by caterpillars and other phytophagous creatures (*Verbascum thapsis*). In the nettle there are stinging hairs which produce an uncomfortable irritation when handled with the bare hands.

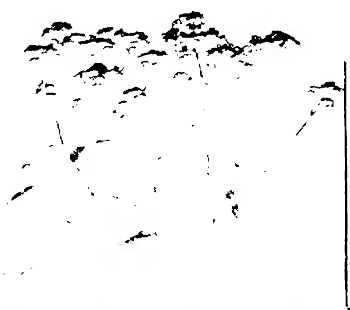


Common Blue Violet (*Viola papilionacea*), spring

Squirrel Corn (*Dicentra canadensis*), early spring

Fire Pink (*Silene virginica*), early summer

Jewel Weed or Touch-Me-Not, (*Impatiens pallida*), early summer



Boneset (*Eupatorium perfoliatum*), late summer

New England Aster (*Aster nova Belgae*), late summer

PLATE XXIX. Common wild flowers. Courtesy Dr. E. M. Gress.

Thorns, spines, poisons, and offensive odors are all defensive structures or processes by which the safety of some plants is assured. There is no doubt that the spines on the stems of the thistle, cacti, wild rose, thorn apple (*Crataegus*), greenbriar; on the leaf margins of holly; and on the midrib of the Jimson weed (*Datura*) and horse nettle are valuable means of protection. The offensive odor of skunk cabbage and the poisonous substances in laurel, bitter nightshade, ivy, poison sumac, and other plants certainly add to the security of these plants.

Carnivorous plants. While it is the general rule that animals devour plants, the process is sometimes reversed; and animals fall victims to the voracious activities of plants. There are numbers of plants which have developed unique devices for capturing animals on which they feed.

The common pitcher plant (*Sarracenia purpurea*) has large, hollow leaves shaped like a pitcher. These leaves are brightly colored with yellowish-green and purple, and the cavities become partly filled with water during rains. Curious insects, probably attracted by the colors or seeking refuge from light or enemies, tumble into these miniature reservoirs and cannot escape because the inner surface is lined with downward-pointing hairs which prevent egress. The unfortunate creatures therefore die and decay. The plant absorbs the substances resulting from the disintegration of the insect bodies. In many such plants there are protein-digesting enzymes which assist in nutrifying the plants. Pitcher plants grow in swampy sections. One species of frog rests near the leaves of pitcher plants and captures insects which enter. Spiders, too, utilize the cavities in the leaves for placing their webs, while several kinds of aquatic insects undergo their metamorphoses in the water in the leaves.

Another insect-catching plant is the sundew (*Drosera*), of which several species are to be found in the northern United States and Canada (Fig. 216). It usually grows in bogs and swamps in rather inconspicuous places. In summer the sundew sends up a slender stalk which bears numerous small white flowers. The red leaves which surround the base of the flower stalk are rounded and about one-half inch in diameter. The upper surface of a leaf is covered with numerous hairs which are short in the middle of the leaf but of increasing length toward the margin. These hairs are glandular, producing a sticky liquid which collects on the ends of the

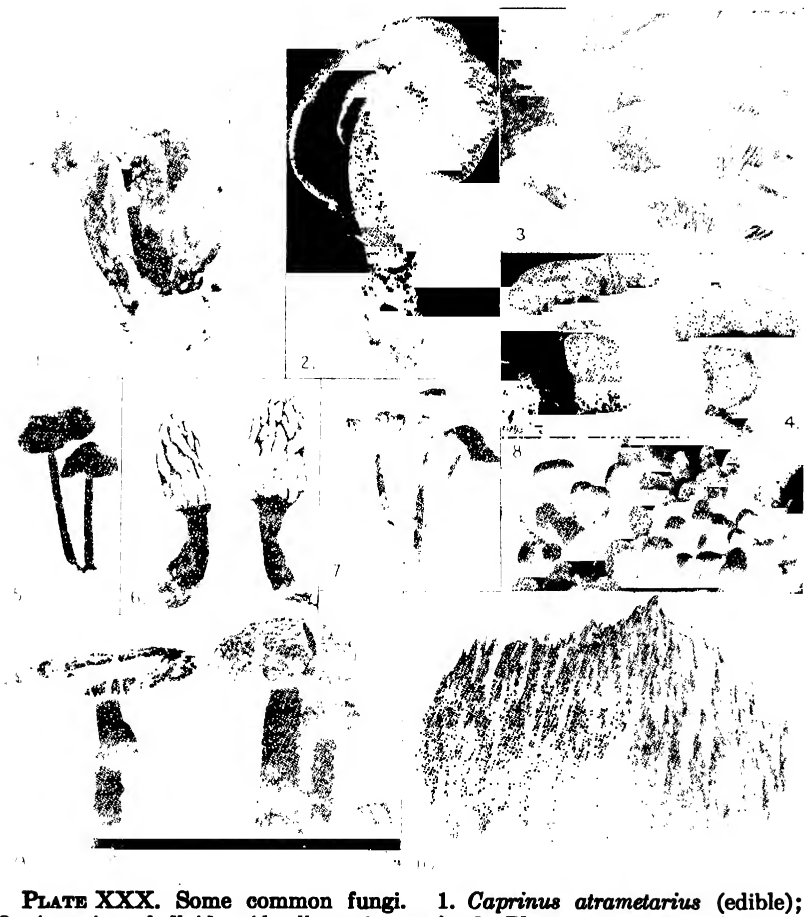


Plate XXX. Some common fungi. 1. *Caprinus atrametarius* (edible); 2. *Amanita phalloides* (deadly poisonous); 3. *Pleurotus ostreatus* (edible); 4. *Agaricus campestris* (edible); 5. *Collybia sp.* (edible); 6. The edible morel (*Morchella esculenta*); 7. *Marasmius oreades* (edible); 8. *Psathyrella disseminata* (edible); 9. *Amanita muscaria* (poisonous); 10. *Hydnum erinaceum* (edible). After Patton and Charles, courtesy U. S. Dept. Agric.

hairs; and they are knobbed at the ends. The glistening of these drops of liquid in the sun accounts for the name sundew. When an insect alights on a leaf, it sticks fast; and the surrounding hairs bend toward the captured victim until many of them are in contact with its body. The protein-digesting enzymes are secreted, and the insect is prepared for absorption. After the insect has been digested, the secretion of enzymes ceases; and the hairs return to their normal upright positions. Strangely enough, inorganic substances do not stimulate the secretion of the digesting fluid.

Venus' flytrap (*Dionaea muscipula*) is a small plant that grows in the Carolinas (Fig. 216). This plant has a rosette of leaves, and each leaf has at its terminal end two oval-shaped lobes which are hinged together at the midrib. The margins of the lobes are covered with numerous sharp teeth. On each lobe there are several very sensitive hairs. When an insect touches one of these hairs, the lobes close suddenly like a trap; and the marginal teeth interlock in such a way as to prevent escape. The victim is held prisoner in the folded leaf until its body is completely digested, after which the trap opens again, ready for another unfortunate visitor.

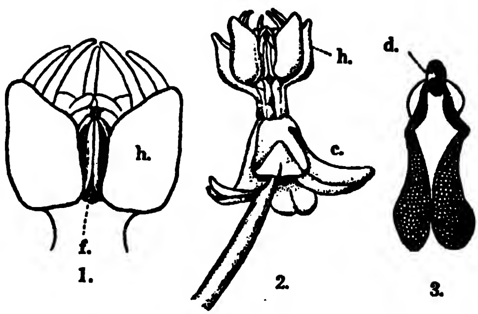


Fig. 218. The milkweed flower. 1. External aspect of fissure; 2. Single flower; 3. Pollinia. c. Corolla; d. Disk (enlarged); f. Fissure leading up to disk and also into stigmatic chamber; h. Hood. From Folsom and Wardle, *Entomology*, courtesy P. Blakiston's Son & Co.

The bladderwort (*Utricularia*) is a widely distributed inhabitant of ditches, ponds, and bogs. There are several species of bladderworts, most of which are truly aquatic. On the submerged leaves of the bladderwort there are numerous small sacs or bladders. The bladders are open at one end, and there is a valve-like lid with downward-pointing bristles at the entrance. When a small insect or larva swims into the bladder, it cannot escape. The captured victims contribute to the nutrition of the plants.

One of the butterworts (*Pinguicula vulgaris*), which grows on wet limestone in the extreme northern sections of the United States

and Canada, is a small plant with a rosette of entire, spatulate leaves which are soft and fleshy. The upper surface of the leaf is covered with glandular hairs to which insects adhere as in sundew. However, the hairs are not motile; but the edges of the leaf bend inward so as to bring many of the hairs into contact with the insect.

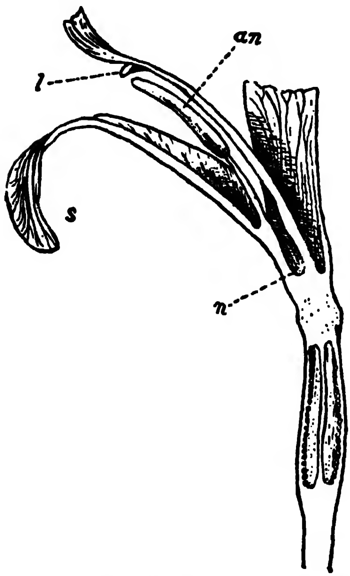


FIG. 219. Section illustrating cross pollination of the iris. *an.* Anther; *l.* Stigmatic lip; *n.* Nectary; Sepal. After Folsom and Wardle, *Entomology,* courtesy P. Blakiston's Son & Co.

There are numerous insect-catching plants throughout the world; and Charles Darwin's book called *Insectivorous Plants* is well worth reading.

Seed dispersal. One of the chief objectives of every living organism seems to be the general distribution of its kind. The advantage to the organism in having its progeny scattered over a wide area is obvious. In addition to increasing the area from which to draw sustenance and thus offering opportunities for a greater number of individuals, a general distribution of a species safeguards its security and perpetuity in other ways. A wide range removes some individuals from the danger of epidemics, fire, and other catastrophes, which are usually limited to a localized section.

Animals effect this distribution by migration, parasitic habits and in other ways. Just as animals utilize wind, water, and other organisms in their efforts to effect a wide distribution of species, the plants, too, have resorted to ingenuous methods of utilizing these agencies for effecting a distribution of their kinds. Many plants produce seeds which have tufts of hair attached to them, and these tufts serve as balloons and add to their buoyancy. The wind transports these seeds sometimes for hundreds of miles. The milkweed, wild lettuce, goldenrod, dandelion, aster, cottonwood, willow, and scores of other plants distribute their progeny in this way. The seeds of the elm, maple, ash, ailanthus, cedar, birch, hemlock, pines, linden or basswood, and numerous others

Fig. 220. Desert vegetation showing the modification of xerophytic plants to arid conditions. From exhibit of Arizona vegetation, Carnegie Mus.

have winged attachments which also adapt them for wind distribution. The tumble weeds, Russian thistle, fire grass, and old-witch grass develop a rounded form. In the fall the plant breaks off near the top and rolls over the ground when blown by the wind. As it bumps along the contacts with the ground shake out the seeds, thus effecting an efficient dispersal. Such plants usually grow on wind-swept prairie lands. The swollen, air-filled, bladder-like fruits of ironwood, ground cherry, and bladder nut are also adapted to wind distribution.

In addition to these methods for effecting dispersal, many plants have their seeds equipped with spines or hooks; and they utilize animal carriers. Probably all of us have assisted plants in their efforts to spread their kind. Spanish needles, sand burs, cockle burs, beggar's ticks, hound's tongue, burs of docks, and seeds of sweet anise are adhesive and cling to the coats of animals or to clothing and in this way are carried to places far from the parent plants. Some plants even have sticky seeds, such as pinks (*Silene*), chickweed (*Cerastium*), and twin flower (*Linnaea*). Other plants bear their seeds in capsules which explode when ripe, and the violence of the opening pod throws the seeds to a considerable distance from the plant on which they are borne. Among these are the common snapdragons, violet, geranium, squirting cucumber, wild touch-me-nots or jewel weeds (*Impatiens*), oxalis, and witch hazel. The fern and some fungi, likewise, violently discharge their spores. The witch hazel (*Hammamelis virginiana*) presents a remarkable example of how the directive forces in nature provide for the survival of nature's progeny. The witch hazel bears its yellow flowers late in the fall. These flowers do not produce ripened seeds until the second year. Consequently, both flowers and seed pods are borne on the plant at the same time. After the surrounding deciduous plants have shed their leaves, the fruits mature; and the pods burst with such violence that the tiny, black, shining seeds are thrown for considerable distances. The fact that the plant does not shoot out its seeds until the other plants have lost their leaves is significant. The timing of the bursting fruits to the period when the masses of foliage, which would certainly impede the progress of the shooting seeds, have been removed, certainly illustrates the wonders of nature's plan. In the legumes such as vetch, the halves of the pod in which the seeds are produced suddenly split apart and curl.

FIG. 221. Spring in a northern wood with trillium, dog-toothed violet, May apple, and dogwood in the foreground. Courtesy Carnegie Mus.

The curling is spontaneous and throws the seeds away from the plants. In the tropical jungles, the bursting pods of some of these explosive fruits is so violent that a report resembling a pistol shot is produced. Some adaptations to dispersal are shown in Fig. 214.

The violent discharge of seeds is effected by both chemical and physical factors in a number of ways. (1) In ferns the action is hygroscopic. A ring of dead tissue, the annulus, suddenly springs back and releases the spores when the atmospheric humidity reaches the proper point. (2) Certain fungi propel their spores when a sudden chemical conversion of glycogen into maltase produces a turgescence. The increase of turgidity is also responsible for the discharge of the seeds in the squirting cucumber (*Ecballium*), *Oxalis*, and *Impatiens*. (3) In some dry fruits the seeds are discharged by the drying of the capsule which splits open. Among these are violets, mosses, pinks, geraniums, witch hazel, mustard, and lotus. (4) Certain fruits are known as mortars, inasmuch as the seeds are so situated as to be forcibly catapulted as from mortars, when the stem is sharply bent. Most of the composites, borages, and mints have their achenes or nutlets placed in the calyx.

Plants which have none of these devices must resort to other methods of dispersal. The berries and aggregate fruits—blackberry, blueberry, wild strawberry, wild grapes—have the seeds enclosed in fleshy, edible masses which are devoured by roaming animals. These seeds, being protected by an indigestible testa, pass through the alimentary tract without being digested and are later deposited in the fecal discharge of the animal, frequently far from the mother plant. Migrating (flying) birds are responsible for the distribution of many plants in this manner. The box huckleberry, for instance, has been found growing in central Pennsylvania, far from its native habitat, having been transported by migrating birds. Many water plants are distributed by migrating waterfowl.

The apple, thorn apple, June berry, persimmon, pawpaw, and stone fruits such as cherries and plums have developed fragrant, attractively colored, and edible fleshy portions around the seeds which attract animals. These fruits are carried away; the fleshy portion is eaten; and the seeds are cast off. In this way distribution is effected.

Plate XXXI. Types of Flowers. 1. Sweet gum (staminate heads); 2. Sweet gum (a pistillate head); 3. Common locust (a drooping raceme); 4. Striped maple (a drooping staminate raceme); 5. Striped maple (a drooping pistillate raceme); 6. Red maple (staminate fascicles); 7. Red maple (pistillate fascicles); 8. Basswood (a drooping cyme); 9. Flowering dogwood (a dense cluster); 10. White ash (a staminate panicle); 11. White ash (a pistillate panicle); 12. Rhododendron (a single flower); 13. Wild black cherry (a raceme); 14. Buttonwood (a head). From Illick, *Pennsylvania Trees*, courtesy Penn. Dept. Forests and Waters.

Many noxious species of plants are to be found growing among kinds that are cultivated and harvested. The seeds of the undesirables are distributed with these, although seed assortment has reduced this to a minimum in recent years. The writer found the Mexican dock (*Rumex mexicanus*) growing in western Pennsylvania. Investigation showed that the field where the dock was found had been planted some years before with alfalfa seed that had been shipped in from the Imperial valley in California. Quite frequently along railroad sidings where cars of grain from distant places are unloaded a number of exotic species of plants may be found growing. The seeds of these have been imported with the grains.

The acorns of oaks and other seeds lacking special structures for transportation depend upon the activities of animals such as squirrels for assisting in distribution. While squirrels dig up many of the nuts they bury, they also forget many of them; and the buried seeds germinate. This type of distribution is rather slow in comparison with the rapid dispersal of plants like the milkweed. Man himself has been a powerful factor in the distribution of plants as well as their insect parasites. The impervious, sac-like fruits of sedges and water lilies, and the mat-like covering of the coconut are adapted to floating in water. The only native coconuts in the United States grew from fruits which were washed ashore by ocean waves. The mangroves of the African west coast and the east coast of South America are identical, the floating fruits having been disseminated by ocean currents. Quite frequently in every part of the world the high flood level is marked with rows of plants, the seeds of which have been deposited by the water.

Climbing plants. Many plants which lack a sturdy woody stem utilize plants and other objects for support in their efforts to reach the sunlight or to secure sustenance from other strata.

The most spectacular climbing plants are the lianas of tropical countries. These lack the mechanical tissues necessary to keep them in an upright position; and they must, therefore, use other plants in order to display their foliage properly. Lianas may cling tightly to the host or they may hang loosely from the lower branches of the giant trees on which the larger plants depend for support.

The most specialized lianas are twiners, and most of these

PLATE XXXII. Flowers and Flower Arrangement. 1. White pine (staminate cluster); 2. White pine (two pistillate); 3. Willow (staminate ament); 4. Willow (pistillate ament); 5. Walnut (staminate ament); 6. Walnut (a pistillate flower); 7. Hickory (staminate ament); 8. Hickory (a pistillate flower); 9. Birch (staminate ament); 10. Birch (a pistillate ament); 11. Beech (a staminate head); 12. Beech (two pistillate flowers); 13. Chestnut (a staminate ament); 14. Chestnut (a pistillate ament); 15. White oak (four staminate aments); 16. White oak (a pistillate flower); 17. Elm (three clusters of incomplete flowers); 18. Mulberry (a staminate spike); 19. Mulberry (a dense pistillate spike); 20. Tulip tree (a complete flower); 21. Papaw (a complete flower). From Illick, *Pennsylvania Trees*, courtesy Penn. Dept. Forests and Waters.

twine in a counterclockwise direction. The bean (*Phaseolus*), bittersweet (*Celastrus*), moonseed (*Menispermum*), and the bitter nightshade (*Solanum dulcamara*) are common examples. However, the hop (*Humulus*) and the bindweed (*Polygonum*) twine in a clockwise direction.

A number of plants produce tendrils which are sensitive to contact with objects. Tendrils are usually modified organs such as branches or leaves. The coils produced have a spring-like effect; and when the wind blows hard the coiled tendril stretches and contracts so as to reduce the danger of detachment or breaking of the stem. Common plants that produce tendrils include the clematis, which uses the stalks of the leaflets; the pea, in which the tendrils are modified leaflets; the smilax in which the tendrils are in the position of stipules which are normally absent in monocotyledons; the grape, where the tendrils are modified branches: and the squash, whose tendrils are probably leaves and shoots.

However, many plants, such as ivy and the Virginia creeper, produce adventitious roots along the stem; and these roots serve to hold the plant in position. Still other plants must be classed as leaners, having no specialized climbing structures; and these grow in such a way as to support themselves by purchase or by spines, as rose bushes and blackberries. Some plants, like the dodder, are parasitic; and they climb over the host plants to secure sustenance. The parasites produce houstonia, or sucking organs, which are modified roots. These organs serve the dual purpose of ingestion and climbing.

Epiphytic and parasitic plants. There are many plants which grow upon others but which do not climb. These are called epiphytes. As a rule, they merely utilize other plants as a means of reaching light and breezes. In the tropics these are extremely abundant, and they assist in forming a thick and dense roof in the jungles. The most prominent of these are lianas, orchids, caladiums, figs, and bromeliads in the tropical regions.

However, Spanish moss, mistletoe, mosses, lichens, and some ferns grow on the trunks and branches of trees and shrubs. Many epiphytes are independent, securing their sustenance from the air or from the débris which collects in their tangled roots. Others, like the fig, mistletoe, and Spanish moss, are partly parasitic and derive considerable of their nutrient from their hosts; while many plants are entirely parasitic, securing all of their nourishment at

duced by the hessian fly, the chrysanthemum stem gall produced by a gall midge, and the galls produced by the grape phylloxera on the stems, roots, and leaves of grapes are sometimes very destructive.

An excessive growth of galls is made at the expense of the health and fruit of the plant which supports them, but on the whole galls do not seriously menace mankind. In fact, many galls have been used for ages in making ink, dyes, and medicines, and in tanning and tattooing. They have also been used as charms by many races of people. Many birds such as goldfinches, chickadees, and woodpeckers find the galls excellent sources of food.

To the naturalist, the gall provides an interesting study in animal association. When a green gall is cut open, a number of creatures are usually found in it. Since there are several or many inhabitants in the gall, it is sometimes difficult to determine which one is the maker. In addition to the gall-maker there may be parasites and diverse "squatters" which find in the gall an excellent shelter. Sometimes spiders, ants, ladybird beetle larvae, and other animals which are definitely known not to form galls are found within them. The larvae of ichneumon flies, braconid wasps, and chalcid flies which are parasitic on the other inhabitants of the gall are also frequently found. The spiders and beetle larvae are there to devour any victims they can find, while the ants are probably attracted by the honey dew secreted by the aphids which are frequently in the gall association. Sometimes old galls, from which the makers have emerged, are used as homes and shelter by other animals. The mason bee is known to nest occasionally in deserted "oak apples."

It has been suggested that galls are formed by diverse animals, including insects. The insects represented include the following orders:

(1) *Homoptera* (aphids or plant lice). These live in open galls since they cannot open closed galls. As a rule, the gall aphids live in pouches or little pocket-like structures lined with hairs and provided with slits or other openings. The rosettes or bunch galls in the apices of plants are usually produced by aphids which live in the curled or otherwise distorted leaves. The jumping plant lice (*Chermidae*) also produce galls occasionally.

(2) *Hymenoptera* (gall wasps and sawflies). The gall wasps (*Cynipidae*) are the chief gall formers, and they are responsible for a great number of closed galls. The sawflies (*Tenthredinidae*), which

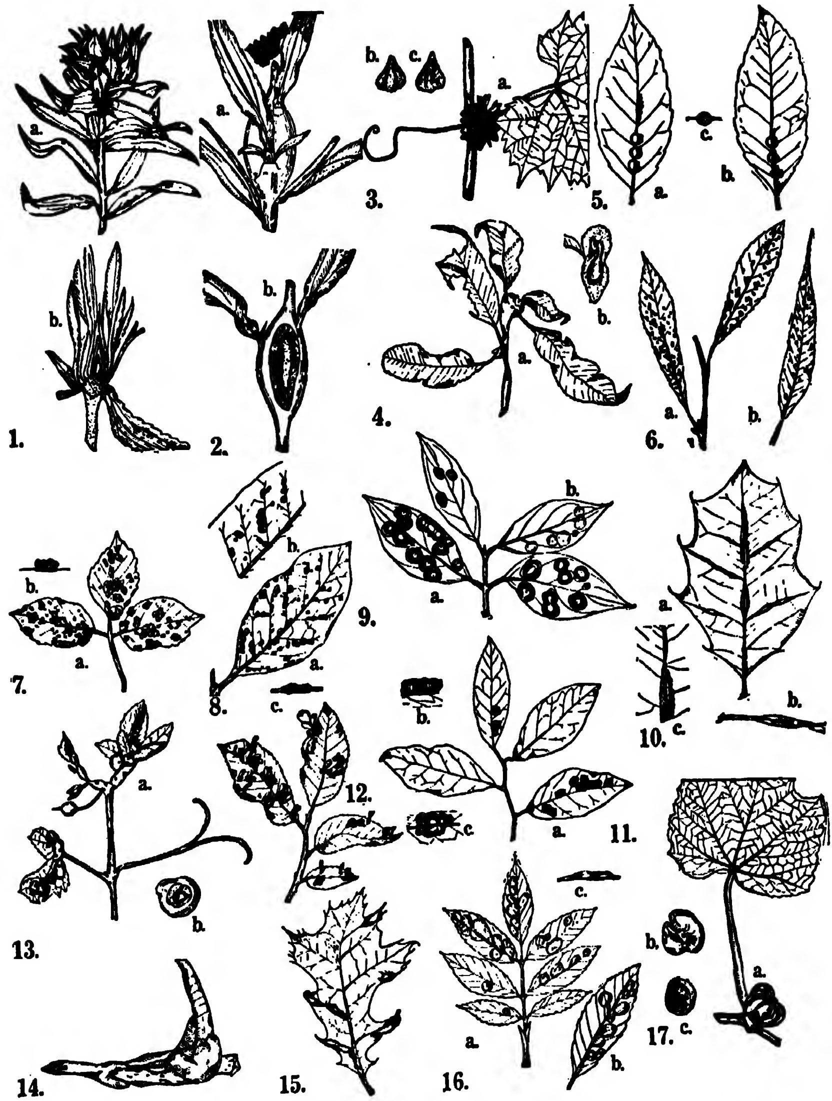


PLATE XXXVI. Plant galls. (See caption on facing page.)

PLATE XXXVI

1. Goldenrod bunch gall on Canada goldenrod (*Solidago canadensis*). Maker—a gall midge (*Rhopalomyia solidaginis*). a. Top of a stalk with a bunch gall; b. Longitudinal section showing the cavity.
2. Elliptical goldenrod gall on Canada goldenrod (*Solidago canadensis*). Maker—a moth (*Gnorischema gallaesolidaginis*). a. External view of the gall; b. Opened gall showing the cavity.
3. Grape filbert gall on frost grape (*Vitis vulpina*). Maker—a gall midge (*Schizomyia coryloides*). a. Twig with a cluster of galls; b. Detailed view of a gall; c. Longitudinal section showing cavities.
4. Wild cherry bud gall (*Prunus serotina*). Maker—a gall midge (*Cecidomyia serotinae*). a. Twig with a gall; b. Longitudinal section of a gall showing the cavity.
5. Ash bullet gall on white ash (*Fraxinus americana*). Maker—a gall midge (*Cecidomyia pellex*). a. Upper surface of leaflet with three galls; b. Under surface of leaflet with three galls; c. Vertical section showing the cavity.
6. Small pocket galls on several willows (glaucous willow—*Salix discolor* and white willow—*S. alba*). Maker—a gall mite (*Eriophyes sp.*). a. Galled leaves of glaucous willow; b. Galled leaves of white willow.
7. Dimple galls on poison ivy leaves (*Rhus toxicodendron*). Maker—a gall mite (*Eriophyes rhois*). a. Galled leaf; b. Vertical section showing the hairs within the depression.
8. Leaf galls on the buttonbush (*Cephalanthus occidentalis*). Maker—a gall mite (*Eriophyes cephalanthi*). a. Upper surface of galled leaf; b. Galls on the under surface of the leaf; c. Vertical section showing the hairs lining the depression.
9. Margined leaf blister galls on dogwood (silky dogwood or kinnikinnik—*Cornus Amomum*). Maker—a gall midge (*Lasioptera corni*). a. Twig with galled leaves; b. Vertical section showing the cavity.
10. Woody vein gall on northern red oak (*Quercus borealis*). Maker—probably a gall wasp. a. Leaf with several galls; b. Detailed view of a gall; c. View with the top sliced off showing cavities.
11. Blueberry leaf gall on high blueberry (*Vaccinium corymbosum*). Maker—a gall midge (*Dasyneura gaylussacii*). a. Twig with several galled leaves; b. Detailed view showing two galls; c. Opened gall showing the cavity.
12. Wild cherry pouch gall (*Prunus serotina*). Galled leaves. Maker—a gall mite (*Eriophyes pedi*).
13. Grape tomato gall on frost grape (*Vitis vulpina*). Maker—a gall midge (*Lasioptera vitis*). a. Twig with numerous galls; b. Section showing the cavity.
14. Maple twig gall on red maple (*Acer rubrum*). External appearance of a gall. Maker—a beetle (*Xylotrechus aceris*).
15. Fusiform vein gall on oak leaves of red oak (*Quercus rubra*). Leaf with several galls.
16. Rose lentil gall (*Rosa carolina*). Maker—a gall wasp (*Rhodites lenticularis*). a. Upper surface of a galled leaf; b. Lower surface of a galled leaf; c. Vertical section of confluent galls showing their cavities.
17. Grape apple gall on summer grape (*Vitis bicolor*). Maker—a gall midge (*Schizomyia pomum*). a. Twig with a gall; b. Appearance of a gall from above; c. Vertical section showing cavities.

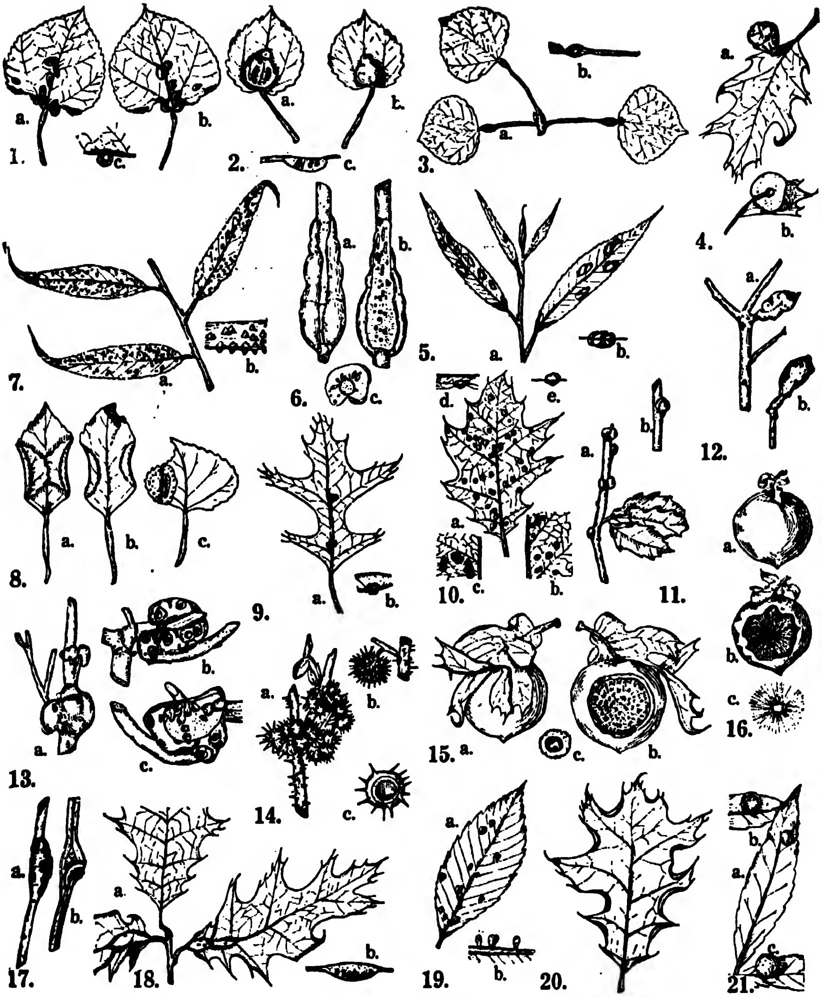


PLATE XXXVII. Plant galls. (See caption on facing page.)

Plate XXXVII

1. Subglobular leaf galls on trembling aspen (*Populus tremuloides*). Maker—a gall midge. a. Upper surface of a leaf showing galls with openings; b. Under surface with galls; c. Longitudinal section showing the cavity.
2. Basal leaf gall on trembling aspen (*Populus tremuloides*). Maker—a gall midge. a. Upper surface showing openings of the gall; b. Under surface showing the gall; c. Longitudinal section showing cavities.
3. Ribbed petiole gall on aspen (*Populus tremuloides*). Maker—a moth (*Ectoedemia populella*). a. Leaves with galls; b. Longitudinal section showing the cavity.
4. Translucent oak gall on red oak (*Quercus rubra*). Maker—a gall wasp (*Amphibolips nubilipennia*). a. Leaf with a gall; b. Longitudinal section showing larval cells and openings.
5. Red leaf galls on crack willow (*Salix fragilis*). Maker—a sawfly (*Pontania hyalina*). a. Galled leaves; b. Detailed view.
6. Gall of the elder stem midge (*Sambucus canadensis*). Maker—a gall midge (*Neolasioptera sambuci*). a. External view of the gall; b. Longitudinal section showing the cavities; c. Cross section showing the cavities.
7. Small pocket galls on black willow (*Salix nigra*). Maker—a gall mite (*Eriophyes sp.*) a. Galled leaves; b. Detailed view.
8. Marginal leaf fold on western cottonwoods (*Populus deltoides*). Maker—probably a moth. a. Under surface of a leaf with two folds; b. Upper surface of a leaf with two folds; c. Upper surface with a fold spread open to show the larva within.
9. Oak pill gall on pin oak (*Quercus palustris*). Maker—a gall midge [*Cincticornia pilulae* (?)]. a. Under surface of a leaf with two galls; b. Detailed view of upper surface.
10. Oak leaf blister galls on red oak (*Quercus borealis* and *Q. velutina*). Maker—a gall midge (probably *Cincticornia simpla*). a. Upper surface of galled leaf; b. Lower surface with galls; c. Old galls with their tops broken off; d. Detailed view of gall from above; e. Longitudinal section.
11. Axillary bud gall on black oak (*Quercus velutina*). Maker—probably a gall wasp. a. Twig with several galls; b. Detailed view of two galls.
12. Apical twig galls on red oak (*Quercus rubra*). Maker—a gall wasp (*Andricus scitulus*). a. External appearance; b. Longitudinal section showing cavities.
13. Gouty oak gall on northern red oak (*Quercus borealis*). Maker—a gall wasp (*Andricus punctatus*). a. External appearance of a gall; b. External view showing large openings; c. Longitudinal section showing cavities.
14. Spiny rose gall (*Rosa carolina*). Maker—a gall wasp (*Rhodites bicolor*). a. Twig with a cluster of galls; b. Detailed view of a gall; c. Opened gall showing the cavity within.
15. Large spongy oak apple on northern red oak (*Quercus borealis*). Maker—a gall wasp (*Amphibolips confluens*). a. External appearance of a gall; b. Opened gall showing spongy material inside; c. Larval cell showing thick wall and larva within.
16. Large empty oak apple on red oak (*Quercus rubra*). Maker—a gall wasp (*Amphibolips inanis*). a. External appearance of the gall; b. Opened gall showing the larval cell supported by fibers; c. Detailed view of larval cell.
17. Poplar twig gall (*Populus deltoides*). Maker—a beetle (*Saperda populnea*). a. External appearance showing the opening; b. Longitudinal section showing the cavity.
18. Midrib and petiole gall on red oak (*Quercus rubra*). Maker—a gall wasp (probably *Callirhytis nigrae* or *C. tumifica*). a. Leaves with galls; b. Vertical section showing cavities.
19. Pocket galls on leaves of American elm (*Ulmus americana*). Maker—a gall mite (*Eriophyes ulmi*). a. Galled leaf; b. Detailed view of several galls.
20. Marginal fold gall on northern red oak (*Quercus borealis*) and pin oak (*Q. palustris*). A leaf with a number of galls.
21. Willow pea gall on glaucous willow (*Salix discolor*). Maker—a sawfly (*Pontania pisum*). a. Gall on a leaf; b. Longitudinal section showing the cavity; c. Detailed view.

Plate XXXVIII. Plant galls. (See caption on facing page.)

Plate XXXVIII

1. Succulent oak gall on pin oak (*Quercus palustris*). Maker—a gall wasp (*Dryophanta palustris*). a. Leaf with a gall; b. Cross section showing the free larval cell within the cavity.
2. Small Fusiform oak leaf gall on pin oak (*Quercus palustris*). Maker—a gall wasp (*Dryophanta notha*). a. Leaf with a gall; b. Gall with the top removed showing the free spindle shaped larval cell within.
3. Small oak apple on northern red oak (*Quercus borealis*). Maker—a gall wasp (*Andricus singularis*). a. Leaf with a gall; b. Detailed view of a gall; c. Opened gall showing the larval cell supported by fibers.
4. Rose blister gall (*Rosa carolina*). Maker—a gall wasp (*Rhodites rosaefolii*). a. Galled leaf; b. Vertical section showing the cavity.
5. Small apical or axillary rosette gall on goldenrod (Canada goldenrod—*Solidago canadensis*). Maker—a gall midge (possibly *Rhopalomyia carolina*). a. Top of a stalk with three galls; b. Longitudinal section of a gall showing the cavity.
6. Poplar stem gall (*Populus deltoides*). Maker—an aphid (*Pemphigus populicaulis*). a. Upper surface of a leaf with a gall; b. Under surface of a leaf showing the spiral opening; c. Cross section showing the cavity.
7 Globular rose leaf gall (*Rosa carolina*). Maker—a gall wasp (probably *Rhodites nebulosis*). a. Galled leaf; b. Detailed view; c. Longitudinal section showing the cavity.
8. Marginal leaf roll on locust (*Robinia Pseudo Acacia*). A leaf with several galled leaflets. Maker—a gall midge (*Obolodiplosis robiniae*).
9. Wooly leaf gall on northern red oak (*Quercus borealis*). Maker—probably the gall wasp (*Callirhytis lanata*). a. Leaf with several galls; b. Detailed view; c. Some of the hairs removed to show the larval cell.
10. Case-making moth gall of the grape on frost grape (*Vitis vulpina*). Maker—a moth. a. Leaf with numerous galls; b. Detailed view of a gall.
11. Buttonbush twig gall (*Cephalanthus occidentalis*). Maker—possibly the gall midge (*Rhabdophaga cephalanthi*). a. Twig with a gall; b. Longitudinal section showing the cavity.
12. Blueberry stem gall on high blueberry (*Vaccinium corymbosum*). Maker—a gall wasp (*Solenozopheria vaccinii*). a. Twig showing a fresh gall; b. Vertical section of a fresh gall showing the cavities; c. External appearance of an old gall; d. Vertical section of an old gall showing the cavities.
13. Red-spotted empty oak apple on red oak (*Quercus rubra*). Maker—a gall wasp (*Dryophanta rubrae*). a. External appearance of the gall; b. Opened gall showing the larval cell supported by fibers; c. Gall of smaller size.
14. Goldenrod ball gall on Canada goldenrod (*Solidago canadensis*). Maker—a gall fly (*Eurosta solidaginis*). a. External view of a gall; b. Vertical section showing the solid material within.
15. Long rose gall (*Rosa carolina*). Maker—a gall wasp (*Rhodites dichlocerus*). a. Twig with a gall; b. Longitudinal section showing cavities; c. Cross section showing cavities.
16. Willow apple gall on beaked willow (*Salix rostrata*). Maker—a sawfly (*Pontania pomum*). a. Under surface of a leaf with two galls; b. Under surface of a leaf with four galls; c. Upper surface of a leaf with four galls; d. Longitudinal section showing the cavity.
17. Poplar petiole gall (*Populus deltoides*). Maker—a moth (*Pemphigus populitransversus*). a. Leaf with a gall; b. Cross section showing the cavity.
18. Vagabond poplar gall (*Populus deltoides*). A twig with a gall. Maker—an aphid (*Pemphigus vagabundus*).

lay their eggs in the stems of plants by inserting their horny ovipositors into them, also produce galls such as the willow pea gall on the glaucus willow (*Salix discolor*).

(3) *Diptera* (gall midges). These two-winged flies vie with the *Cynipidae* for honors in producing the greater number of galls. The marginal leaf roll on the locust and numerous others are produced by gall midges.

(4) *Lepidoptera* (caterpillars). While most caterpillars are leaf-eaters, a few of them produce galls on the host plants. The very common elliptical swellings on the stems of goldenrods are produced by a moth larva, *Gnorischema gallae-solidaginis*. The ribbed petiole gall on the petioles of the trembling and large-toothed aspens are also produced by a moth caterpillar, *Ectodemia populella*.

(5) *Coleoptera* (beetles). Most beetles have chewing mouth parts, and many of them devour the bodies of plants. The injury done by their feeding frequently produces galls on the plants which they eat. The swellings on the stems of blackberries are produced by the feeding activities of the red-necked cane borer, *Agrilus ruficollis*. A similar swelling on the raspberry is the work of the raspberry cane girdler, *Oberea bimaculata*. The longhorn beetle, *Saperda*, causes swellings on the stems of poplars.

For a list of common galls and their formers, see Plates XXXVI, XXXVII, XXXVIII.

BIBLIOGRAPHY

Plants

Anderson, W. A., *The Ferns of Tennessee*. Univ. of Tenn. Press, 1929.
Arthur, J. C., *The Plant Rusts*. John Wiley and Sons, 1929.
——, *Manual of the Rusts in the United States and Canada*. Purdue Research Foundation, 1934.
Atkinson, G. F., *Mushrooms, Edible, Poisonous, etc. Studies in American Fungi*. Andrus, 1903.
Bailey, L. H., *Manual of Cultivated Plants*. Macmillan, 1924.
Bayleat, R. M., *Hayfever and Asthma*. Davis, Philadelphia, 1916.
Beecraft, W. I., *Who's Who among the Ferns*. Moffat Yard, 1910.
——, *Who's Who among the Wild Flowers*. Moffat Yard, 1910.
Bennett, F. T., *Outlines of Fungi and Plant Diseases*. Macmillan, 1924.
Bequaert, J., "Ants in Their Diverse Relations to the Plant World," *Bull. Am. Mus. Nat. Hist.*, Vol. 45, 1922, pp. 333–583.
Bews, J. W., *The World's Grasses*. Longmans Green, 1929.

Blakeslee, A. F., and Jarvis, C. D., *Trees in Their Winter Condition.* Macmillan, 1913.

Blanchan, Neltje, *Wild Flowers Worth Knowing.* Doubleday Page, 1922.

Blatchley, W. S., *The Indiana Weed Book.* Nature Pub. Co., Indianapolis, 1920.

Bower, F. O., *Plants and Man.* Macmillan, 1925.

——, *Primitive Land Plants.* Macmillan, 1935.

Britton, N. L., and Brown, A., *Illustrated Flora of the Northern United States, Canada, and the British Possessions*, 3 vols. Scribner, 1913.

Brown, W. H., *The Plant Kingdom.* Ginn, 1935.

Burkill, I. H., *Insect Vision in Connection with Flower Fertilization.* Singapore Nat. 5, 1925, pp. 23–46.

Cady, D. C., *The Ferns of North America.* S. E. Cassino, 1880.

Campbell, D. H., *The Structure and Development of Mosses and Ferns.* Macmillan, 1913.

——, *An Outline of Plant Geography.* Macmillan, 1926.

Cannon, W. A., *Physiological Features of Roots with Special Reference to the Relation of Roots to the Aeration of the Soils.* Carnegie Inst. Wash. Pub. 368, 1925, p. 169.

Chase, Mrs. Agnes, *First Book of Grasses.* Macmillan, 1922.

Chestnut, V. K., *Principal Poisonous Plants of the United States.* U. S. Dept. Agric. Bull. 20, 1898.

Clements, F. E., *Minnesota Mushrooms.* Minn. Plant Studies IV, 1910.

——, *Plant Succession.* Carnegie Inst. Wash. Pub. 242, 1916.

Clements, F. E., and Long, F. L., *Experimental Pollination: an Outline of the Ecology of Flowers and Insects.* Carnegie Inst. Wash. Pub. 336, 1923, p. 274.

Clements, F. E., and others, *Plant Competition.* Carnegie Inst. Wash. Pub. 398, 1929.

Clute, W. N., *Our Ferns and Their Haunts.* Stokes, 1901.

——, *Fern Allies of North America.* Stokes, 1928.

Collins, F. S., *The Green Algae of North America.* Tufts College Stud., Vol. II, 1909, No. 3. Supplement, 1912, Vol. III, No. 2.

Conard, H. S., *The Waterlilies: a Monograph of the Genus Nymphaea.* Carnegie Inst. Wash. Pub. 4, 1905.

Conn, H. W., and Webster, L. W., *A Preliminary Report on the Algae of Fresh Water of Connecticut.* Conn. Geol. and Nat. Hist. Surv. Bull. 10, 1908.

Cosens, A., *A Contribution to the Morphology and Biology of Insect Galls.* Trans. Canadian Inst. 9, 1913, pp. 297–387.

Coulter, J. M., and others, *A Textbook of Botany*, Vol. II, Ecology. American Book Co., 1911.

Creevy, C. A., *Flowers of Field, Hill, and Swamp.* Harper, 1897.

Crocker, W., *Seeds: Their Tricks and Traits.* Jour. N. Y. Bot. Gardens No. 26, 1925.

Dana, Mrs. W. S., *How to Know the Wild Flowers.* Scribner, 1899.

Darwin, Charles, *Insectivorous Plants.* Appleton, 1895.

Durand, H., *Wild Flowers and Ferns in Their Homes and in Our Gardens.* Putnam, 1925.

Fagan, M. M., "The Uses of Insect Galls," *Amer. Nat.*, Vol. 52, 1918, pp. 155–176.

Felt, E. P., "Gall-Insects and Their Relation to Plants," *Sci. Monthly*, Vol. 16, 1918, pp. 509–525.

Fink, Bruce, *The Lichens of Minnesota.* Smithson. Inst. U. S. Nat. Mus. Contr. U. S. Nat. Herbarium, Vol. 14, 1910, Part I.

——, *The Lichen Flora of the United States.* Univ. of Mich. Press, 1935.

Francis, M. E., *Book of Grasses.* Doubleday Page, 1912.

Gager, C. S., *Fundamentals of Botany.* Blakiston, 1916.

Garner, W. W., and Allard, H. A., "Effect of the Relative Length of Day and Night and Other Factors of the Environment on Growth and Reproduction in Plants," *Jour. Agric. Research*, Vol. 18, 1920, pp. 553–606.

Georgia, Ada M., *Manual of the Weeds.* Macmillan, 1914.

Giardini, G. I., "A Preliminary Report on the Lichens of Western Pennsylvania," *The Biologist*, Vol. XXV, Nov., 1922.

Gibson, W. H., *Our Edible Toadstools and Mushrooms and How to Distinguish Them.* Harper, 1903.

Gray, Asa, *How Plants Grow.* S. C. Griggs, 1868.

——, *Manual of Botany.* American Book Co., 1908.

Gress, E. M., *Grasses of Pennsylvania.* Pa. Dept. Agr. Bull. 384, 1924.

——, *Pennsylvania Weeds.* Pa. Dept. Agr. Bull. 416, 1925.

——, *Common Wild Flowers of Pennsylvania.* Times Tribune Co., Altoona, 1928.

——, *Poisonous Plants of Pennsylvania.* Pa. Dept. of Agr. Bull. 531, 1935.

Grout, A. J., *Mosses with a Hand Lens.* C. T. Lewis Co., 1924.

——, *Moss Flora of North America, North of Mexico.* Privately printed, 1928.

Hardy, M. E., *The Geography of Plants.* Oxford Univ. Press, 1925.

Harshberger, J. W., *Textbook of Pastoral and Agricultural Botany.* Blakiston, 1920.

Henkel, Alice, *Weeds Used in Medicine.* U. S. Dept. Agric. Exp. Sta. Bull. 188, 1904.

——, *Wild Medicinal Plants of the United States.* U. S. Dept. Agric. Bur. Plant Ind. Bull. 89, 1906.

——, *American Root Drugs.* U. S. Dept. Agric. Bur. Plant Ind. Bull. 107, 1907.

Henkel, Alice, *American Medicinal Barks.* U. S. Dept. Agric. Bur. Plant Ind. Bull. 139, 1909.

——, *American Medicinal Leaves and Herbs.* U. S. Dept. Agric. Bur. Plant Ind. Bull. 219, 1911.

——, *American Medicinal Flowers, Fruits, and Seeds.* U. S. Dept. Agric. Bur. Plant Ind. Bull. 26, 1913.

Hitchcock, A. S., *Textbook of Grasses.* Macmillan, 1914.

——, *Manual of the Grasses of the United States.* U. S. Dept. Agric. Misc. Pub. No. 200, 1935.

Jackson, B. D., *A Glossary of Botanic Terms.* Lippincott, 1916.

Jennings, O. E., *A Botanical Survey of Presque Isle, Erie, Pennsylvania.* Ann. Carnegie Mus., Vol. V, 1909.

——, *A Manual of the Mosses of Western Pennsylvania.* Published by author, 1913.

——, *Classification of the Plant Societies of Central and Western Pennsylvania.* Proc. Pa. Acad. Sci., Vol. I, 1927.

Jones, F. M., "Pitcher Plant Insects," *Ent. News,* Vol. 15, 1904, No. 14.

Knuth, Paul, *Handbook of Flower Pollination.* Oxford Press, 1906.

Lamson-Scribner, F., *Grasses of Tennessee.* Tenn. Agr. Exp. Sta., Vol. 7, 1894, No. 1.

Lindsay, T. S., *Plant Names.* Macmillan, 1923.

Loundsberry, A., *Guide to the Wild Flowers.* Stokes, 1899.

Lovell, J. H., *The Flower and the Bee.* Scribner, 1918.

Macbride, T. H., *North American Slime Molds.* Macmillan, 1922.

——, *The Myxomycetes.* Macmillan, 1934.

Macdougal, D. T., and Cannon, W. A., *The Conditions of Parasitism in Plants.* Carn. Inst. Wash. Pub. 129, 1910.

Marshall, N. L., *Mosses and Lichens.* Doubleday Page, 1914.

——, *The Mushroom Book.* Doubleday Page, 1923.

Matheny, W. A., *Seed Dispersal.* Slingerland-Comstock Co., 1935.

Matthews, F. S., *Fieldbook of American Wild Flowers.* Putnam, 1927.

McDougall, W. B., *Mushrooms, a Handbook of Edible and Inedible Species.* Houghton Mifflin, 1925.

——, *Plant Ecology.* Lea and Febiger, 1931.

McIlvaine, C., and Macadam, R. K., *One Thousand American Fungi.* Bobbs Merrill, 1912.

Muenscher, W. C., *Weeds.* Macmillan, 1935.

——, *Keys to Woody Plants.* Published by the author at Ithaca, N. Y., 1930.

Nichols, G. E., "A Working Basis for the Ecological Classification of Plant Communities," *Ecology,* Vol. 4, 1923, pp. 11–23, 154–179.

Pammel, L. H., *A Manual of Poisonous Plants.* Torch Press, Cedar Rapids, Iowa, 1910.

Pammel, L. H., *Weeds of Farm and Garden.* Orange Judd, 1911.
Parkhurst, H. E., *Trees, Shrubs, and Vines of Northeastern United States.* Scribner, 1903.
Parsons, Frances, *How to Know the Wild Flowers.* Scribner, 1900.
Patterson, F. W., and Charles, V. K., *Mushrooms and Other Common Fungi.* U. S. Dept. Agric. Bull. 175, 1915.
Peterson, Maude G., *How to Know Wild Fruits.* Macmillan, 1905.
Pieters, A. J., *The Plants of Western Lake Erie with Observations on Their Distribution.* Bull. U. S. Fish Comm. 21, 1901.
Piper, C. W., *Flora of the State of Washington.* U. S. Nat. Mus., Vol. XI, 1906.
Rehder, A., *Manual of Cultivated Trees and Shrubs.* Macmillan, 1934.
Robbins, W. M., and Remaley, F., *Plants Useful to Man.* Blakiston, 1935.
Roberts, E. A., and Rehmann, E., *American Plants for American Gardens.* Macmillan, 1929.
Rolfe, R. T., and F. W., *Romance of the Fungus World.* Lippincott, 1926.
Seward, A. C., *Plants: What They Are and What They Do.* Macmillan, 1932.
Sinnott, E. W., *Botany, Principles and Problems.* McGraw-Hill, 1929.
Skene, M., *The Biology of Flowering Plants.* Macmillan, 1924.
Skinner, C. M., *Myths and Legends of Flowers, Trees, Fruits, and Plants.* Lippincott, 1911.
Stevens, F. L., *The Fungi Which Cause Plant Disease.* Macmillan, 1913.
Tansley, A. G., *Practical Ecology: a Guide for Beginners in Field Study of Plant Communities.* Dodd Mead, 1923.
Taylor, Norman, *A Guide to the Wild Flowers East of the Mississippi and North of Virginia.* Greenberg, 1928.
Thomas, W. S., *Common Gilled Mushrooms.* Putnam, 1928.
Transeau, E. G., *The Science of Plant Life.* World Book Co., 1919.
Underwood, L. M., *Moulds, Mildews, and Mushrooms.* Henry Holt, 1899.
——, *Our Native Ferns and Their Allies.* Henry Holt, 1900.
Vasey, G. C., *Illustrations of North American Grasses.* U. S. Dept. Agric. Div. Botany, 1891.
Viosca, Percy, Jr., "Irises of Louisiana," *The Flower Grower*, Sept., 1932.
Walton, G. L., *The Flower Finder.* Lippincott, 1914.
Ward, F. K., *Romance of Plant Hunting.* Longmans Green, 1924.
Waters, C. E., *Ferns.* Henry Holt, 1903.
Weaver, J. E., and Clements, F. E., *Plant Ecology.* McGraw-Hill, 1929.
Weed, C. M., *Seed Travelers.* Ginn, 1898.

Plant Galls

Ashmead, W. H., "Description of New Cynipidous Galls and Gall Wasps in the United States National Museum," *Proc. U. S. Nat. Mus.*, Vol. XIX, 1897, pp. 113–136.

Banks, Nathan, "A Treatise on the Acarina, or Mites," *Proc. U. S. Nat. Mus.*, Vol. XXVIII, 1904, pp. 1–114.

Bassett, H. F., *Descriptions of Several Supposed New Species of Cynips, with Remarks on the Formation of Certain Galls*, Proc. Ent. Soc. Phila., Vol. II, 1868 to 1869, No. 3, pp. 323–333.

Beutenmüller, William, "Catalogue of Gall-Producing Insects Found within Fifty Miles of New York City, with Descriptions of Their Galls and of Some New Species," *Am. Mus. Nat. Hist.*, Vol. IV, 1904, No. 1, Art. XV, pp. 245–268.

——, "The Insect Galls of the Vicinity of New York City," *Am. Mus. Jour.*, Vol. IV, 1904, No. 4.

Bioletti, F. T., *The Phylloxera of the Grape Vine.* Calif. Agric. Exp. Sta. Bull. 131, 1901.

Cannon, W. A., "The Gall of the Monterey Pine," *Amer. Nat.*, Vol. XXXIV, 1900, No. 406, pp. 801.

Connold, E. T., *Plant Galls.* Adlard and Son, 1909.

Cook, M. T., *Galls and Insects Producing Them.* Bull. No. 8 Ohio State Univ., Parts I and II, 1902; Bull. No. 11, Parts III, IV, and V, 1903; Bull. 17, Parts VI to IX, 1904.

——, *Preliminary List of Gall-producing Insects Common to Indiana.* Proc. Ind. Acad. of Sci., 1902 to 1904.

Cosens, A., *A Contribution to the Morphology and Biology of Insect Galls.* Trans. Canadian Inst. 9, 1913.

Fagan, M. M., "The Uses of Insect Galls," *Amer. Nat.*, Vol. 52, 1918, pp. 155–176.

Felt, E. P., *A Study of Gall Midges.* N. Y. State Mus. Bulls. 165, 175, 180, 257 (1913 to 1925).

——, *A Key to American Insect Galls.* N. Y. State Mus. Bull. 200 (1918).

——, "Gall Insects and Their Relations to Plants," *Sci. Monthly*, Vol. 16, 1918, pp. 509–525.

Garman, H., *The Phytopti and Other Injurious Plant Mites.* 12th Rep. Ill. State Entomologist, 1885, pp. 123–143.

——, *A Plum Twig Gall Produced by a Mite.* 7th Ann. Rep. Ky. Agric. Exp. Sta., 1894.

Gourley, J. E., *One Hundred Plant Galls of Western Penna.* Univ. of Pittsburgh thesis, 1933.

Kinsey, A. C., *The Gall Wasp Genus Cynips.* Ind. Univ. Studies 16, 1929.

Osten-Sacken, Baron R., *On the Cynipidae of the North American Oaks and Their Galls.* Proc. Ent. Soc. Phila., Vol. I, 1867 to 1868, No. 3, pp. 47–72.

——, *Contributions to the Natural History of the Cynipidae of the United States and Their Galls.* Proc. Ent. Soc. Phila., Vol. II, 1868 to 1869, pp. 331–386.

Osten-Sacken, Baron R., *Biological Notes on Diptera (Galls) on Solidago.* Trans. Amer. Ent. Soc., Vol. II, 1868 to 1869, pp. 299–305.

Pergande, Theodore, *The Life History of Two Species of Plant Lice Inhabiting Both Witch Hazel and Birch.* Tech. Series, No. 9, U. S. Dept. Agric., Div. of Ent., 1901.

——, *North American Phylloxerinae Affecting Hicoria (Carya) and Other Trees.* Proc. Dav. Acad. Sci., Davenport, Iowa, Vol. IX, 1904, pp. 185–273.

Rilev, C. V., *The Grape Phylloxera, Phylloxera vastatrix, Planchon.* 3rd, 4th, 5th, 6th, 7th, 8th Ann. Reps. of Noxious and Beneficial and Other Insects of the State of Missouri, 1869 to 1877.

——, *Jumping Seeds and Galls.* Proc. U. S. Nat. Mus., Vol. 5, 1883.

Rothera, G. B., "On the Aetiology and Life History of Some Vegetal Galls and Their Inhabitants," *Nat. Sci.*, Vol. III, 1893, No. 21.

Shimer, Henry, *A Summer Study of Hickory Galls, with Description of Supposed New Insects Bred Therefrom.* Trans. Amer. Ent. Soc., 1869, pp. 386–398.

Stebbins, F. A., *Insect Galls of Springfield, Mass., and Vicinity.* Springfield Museum of Nat. Hist., 1910.

Taylor, Fern L., *The Plant Galls of Presque Isle.* Univ. of Pittsburgh thesis, 1932.

Thompson, M. T., *Illustrated Catalogue of American Insect Galls.* Privately printed, 1915.

Walsh, B. D., *On Insects, Coleopterous, Hymenopterous, and Dipterous, Inhabiting the Galls of Certain Species of Willows.* Proc. Ent. Soc. Phila., Vol. III, 1869 to 1870, pp. 543–644 (id. Vol. VI, pp. 223–288, 1880).

CHAPTER XXI

THE STUDY OF TREES

Characters by Which Trees Are Identified

In the study of trees there are numerous characters by which individual identities are established. The principal characters are:

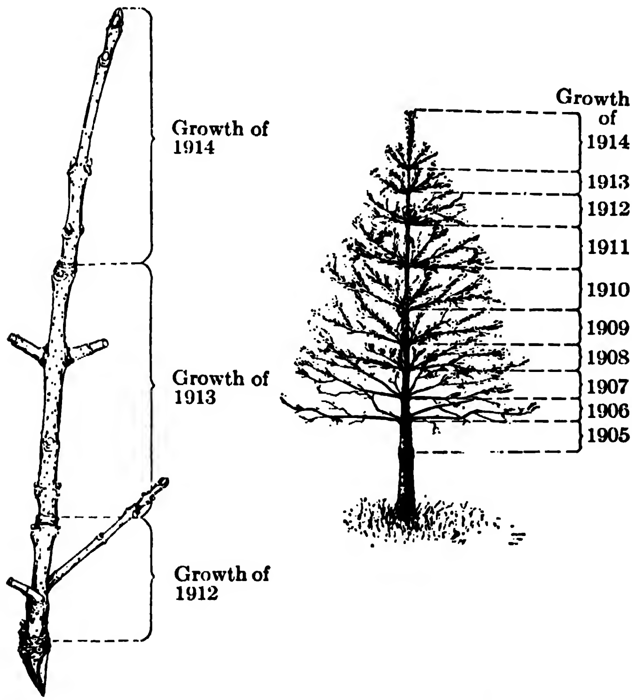


Fig. 222. The growth of trees. After Illick, *Pennsylvania Trees*, courtesy Penn. Dept. Forests and Waters.

form or outline, stem, bark, twigs, leaf scars, leaves, flowers, and fruits. However, only two or three of these characteristics are necessary for placing the identity of any single species.

The outline. The first thing to be noticed about a tree is its outline or silhouette (Plates XXXIII, XXXIV, and XXXV). The

evergreens are readily identified as such by their distinct conical shape. Under normal conditions each species conforms to a definite outline although this may be greatly modified by pruning, crowding, injury by winds, and by exposure. The American elm is wedge- or fan-shaped; the silver maple is broadly cylindrical; the Norway maple is roundish; the pines, spruces, and hemlocks are conical; and the lombardy poplar is a narrow, cylindrical shaft, tapering slightly toward the apex.

The stem. The trunk or stem is also characteristic, as a rule. In the evergreens the main stem or trunk extends from the ground to the tip as a tapering, unbranched bole. Usually the branches radiate from the stem in whorls. A trunk of this character is called *excurrent.* In most of the other trees the trunk begins to branch at some distance above the ground, and the main stem is lost in a multiplicity of smaller branches. Such a trunk is called *deliquescent,* since the main stem melts away into numerous small branches. The different species show many modifications of the splitting of the main trunk, as will be seen later.

The bark. The bark is an almost unmistakable feature in many trees (Plates XXXV and XXXIX). Its color and topography, as well as the manner in which it is shed, are frequently marks of identification. The smooth, whitish bark of the elm; the white, paper-like bark on the white birch; the dark and light greenish-yellow markings of the sycamore which give the bark a mottled appearance; the thin, smooth, chestnut brown covering of the birch and cherry, which peels off in narrow horizontal strips; and the yellowish-green bark of the willows suggest the value of bark color notation in remembering trees. The Carolina poplar has ashy gray bark with deep longitudinal fissures; the shagbark hickory sheds its bark in very long, rectangular strips which become loose at the bottom and peel upward; the ash has a bark with medium fissures which are diamond-shaped; the silver maple has a dark brown bark which is shed in small, rectangular strips which become loose at both ends and curl outward until they drop off. When the strips are pulled off, a cinnamon red color is revealed at the place of attachment; in pines and spruces the bark is scaly; in the black gum the bark is broken up into small, rectangular blocks, giving it the appearance of alligator hide; the bark of the white cedar is split into shreds. There are many other bark characters such as inner color, depth of furrows, direction of the fissures, and especially the texture and

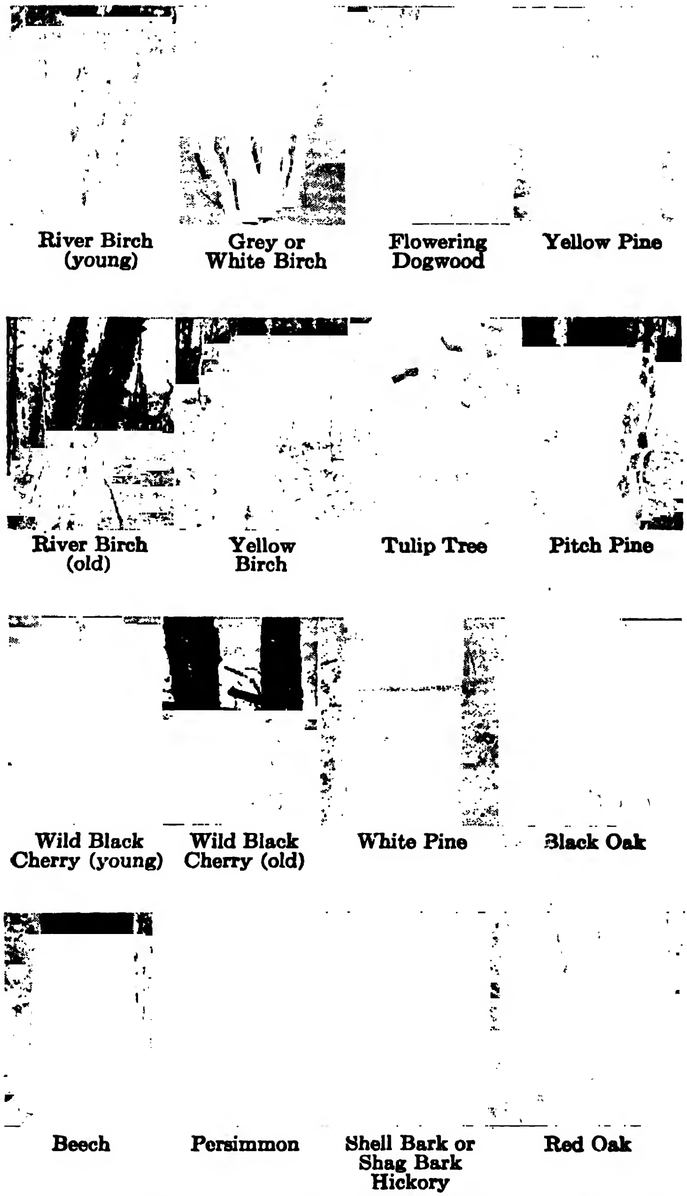


PLATE XXXIX. The bark of some common trees. From Illick, *Pennsylvania Trees*, courtesy J. S. Illick and Penn. Dept. Forests and Waters.

color of the bark on the younger branches. Age effects marked changes in many of these characters.

Leaf scars. On many trees, the scars left by the falling leaves are large and conspicuous. On many others, while the scars are small, they are unique; and they are of great assistance in establishing identities, especially in winter when the leaves, flowers, and fruits which are the ordinary means of determining identities are absent. The leaf scars indicate the manner in which leaves are borne; they may be round, oval, elliptical, ovoid, heart-shaped, shield-shaped, crescent-shaped, lobed, or triangular. The leaf scar also shows the position of the vascular bundles which formed the connection between the leaf and the branch. These appear as corky dots on the leaf scar. Through these bundles the interchange of foodstuffs between the leaf and twig is effected. The scars are especially prominent on the buckeye, catalpa, button wood, ailanthus, walnut, ash, and poplar trees.

Leaves. To the average person leaves are of primary importance in tree identification. The functions and some of the characters of leaves have already been discussed. In considering leaves from the standpoint of their being of value in the establishing of identities, a number of characters must be kept in mind.

Leaves are either simple or compound (Fig. 223). Simple leaves have blades which are united into one piece regardless of the extent to which the margins may be cut in. Compound leaves are composed of a number of smaller leaflets attached to the main stem. Compound leaves may have all of the leaflets originate in one place as in the buckeye (palmately compound), or the leaflets may be scattered along the main stem or petioie as in the locust (pinnately compound). Sometimes the leaf may be doubly compounded; that is, having the main stem branched, with the branches bearing leaflets, as is the case in the Kentucky coffee tree and ailanthus.

In pinnately compound leaves there may be a single terminal leaflet, as in the common locust; or the terminus may have two leaflets, as in the honey locust.

The point at which a leaf is attached to the stem is called a node. The arrangement of leaves is of great importance. Leaves may be alternate (1 at a node), opposite (2 at a node), or whorled (3 or more at a node). The shape is perhaps the usual leaf character used by most people. It has already been suggested that leaves may be needle-like, awl-like, scale-like, or broad and flat. Of the latter

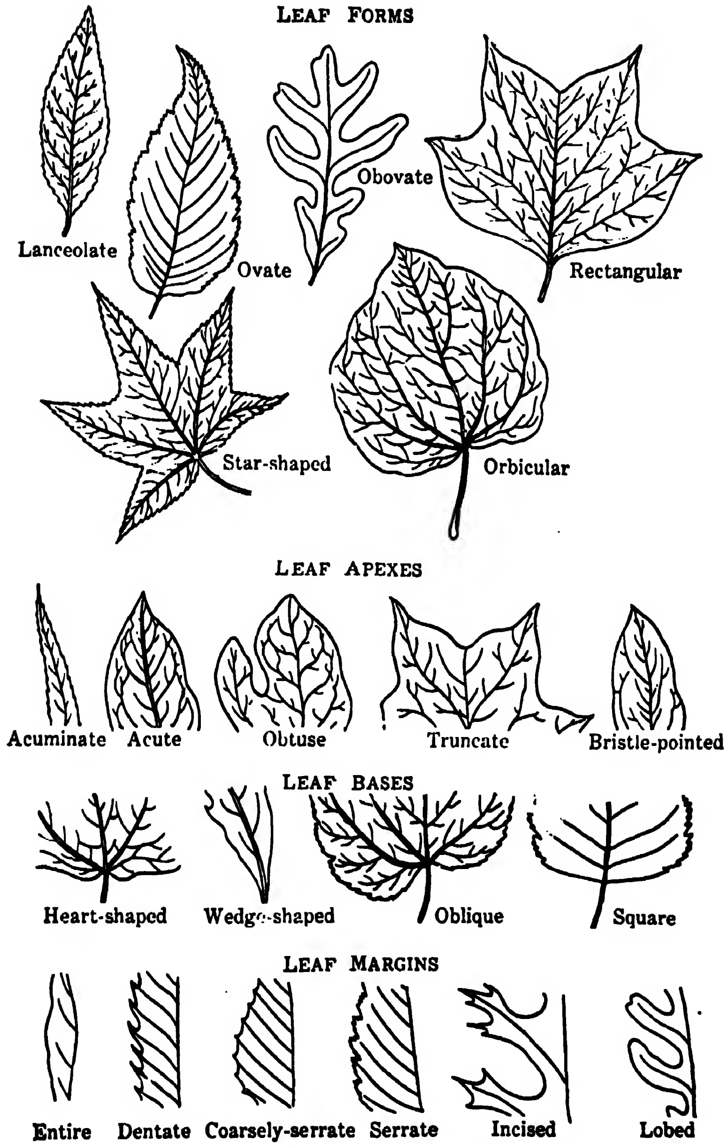


FIG. 223. Leaf characters. From Illick, *Pennsylvania Trees*, courtesy Penn. Dept. Forests and Waters.

there are many variations in size, shape, and texture. The base and apexes also show wide and important variations in different species (Fig. 223).

The margin or edge serves also to place the leaf properly. It may be toothed doubly, singly, coarsely, or finely; or it may be wavy, lobed, or smooth. Sometimes the venation is a distinguishing feature (Fig. 223).

The stem or petiole of the leaf often exhibits outstanding features. In the Carolina poplar the stem is laterally compressed. In the Norway maple it contains an acrid, milky sap. In other cases the petiole may be enlarged and hollow or clasping at the base; or it may be circular, heart-shaped, flat, or triangular in cross-sectional outline.

Flowers. During limited seasons, flowers are often easy and unmistakable features of trees. As a general rule, the flowers of trees are not conspicuous, although there are some exceptions. Some trees bear their flowers early in the spring before the leaves have appeared or fully developed. Others bloom late in the spring or in early summer. The witch hazel does not get its flowers until late in the fall. In early spring the service berry or June berry (*Amelanchier*) bursts into bloom; and its showy white flowers produce a prominent, polka-dot effect on the wooded hillsides. Then the maples with their diminutive blossoms cast a reddish sheen upon the roof of the forest. There follows a beautiful succession of floral displays including the dogwoods, lindens, alders, hazelnuts, wild cherries, willows, chestnut, cottonwood, ailanthus, wild crab-apple, and fruit trees.

The buckeye, catalpa, sumac, umbrella tree, magnolia, wild crabapple, June berry, hawthorn, locust, mountain ash, and tulip tree are especially noted for their showy flowers.

The fruit. The fruit is the ripened ovary; and when this is edible, it is frequently the only means by which many people can identify a tree (Fig. 226). However, the fruit is occasionally the surest means of establishing correct identities. This is especially true of the oaks and hickories.

There are many forms of fruits. Usually they are classified as *dry* and *fleshy*, but there are many variations within these two groups. Dry fruits are those which lack flesh or pulp and are represented by acorns, maple, and ash seeds. Fleshy fruits include plums, cherries, apples, persimmons, haws, papaws, and berries.

Some fruits split open along definite lines to discharge seeds. These are called dehiscent fruits. The fleshy fruits do not open and

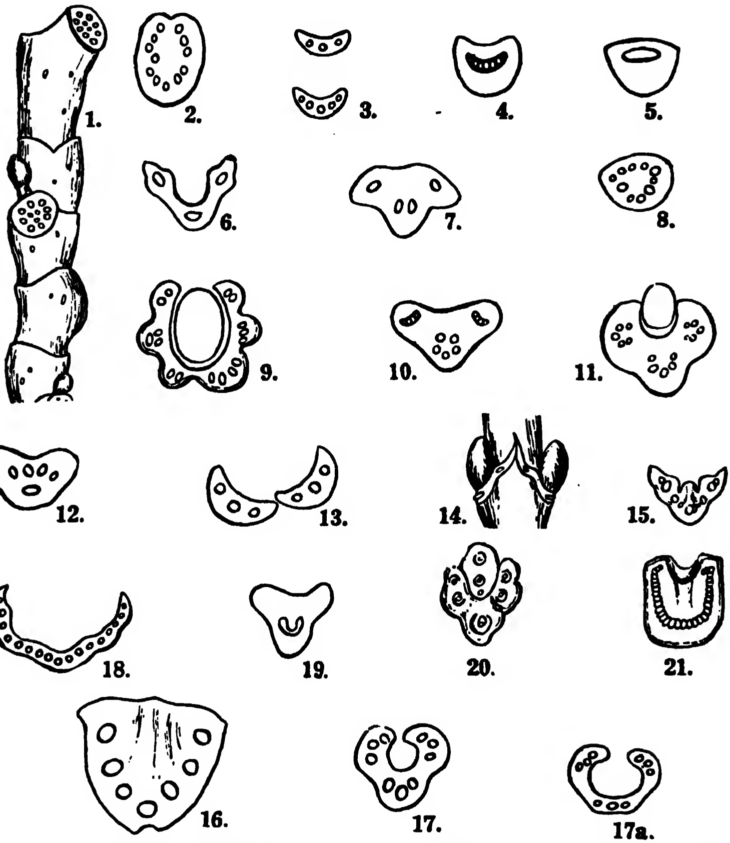


FIG. 224. Types of leaf scars and bundle scars. 1. Tulip tree; 2. Catalpa; 3. American hornbeam; 4. Sassafras; 5. Persimmon; 6. Maple; 7. Poplar; 8. Red mulberry; 9. Buttonwood; 10. Chestnut; 11. Walnut; 12. Basswood; 13. Birch; 14. Box elder; 15. Papaw; 16. Horse chestnut; 17. Dwarf sumac; 17a. Staghorn sumac; 18. Hercules' club; 19. Sour-wood; 20. Kentucky coffee tree; 21. Ash. From Illick, *Pennsylvania Trees*, courtesy Penn. Dept. Forests and Waters.

are said to be indehiscent. Dry fruits may be either dehiscent or indehiscent.

The commonly recognized types of fruits include the following: the *pome*, such as apples and haws; the *drupe*, which may be compound as the hedge apple or osage orange, or single as the choke-

cherry, hackberry, or sassafras; the *nut*, as the acorn, beechnut, hickory, basswood, and walnut; the *samara*, represented by the seeds of elm, ailanthus, ash, and maple; the *follicle*, such as laurel, magnolia, and umbrella tree; the *capsule*, of aspen, willow, sweet gum; the *cone*, of pines, spruces, tulip tree; the *legume*, such as the pods of locust, redbud, and Kentucky coffee tree; and the *collective* or *aggregate* fruits such as the mulberry. Some of these types are shown in Fig. 226.

A study of fruits will reveal that on those plants which depend upon animals for the distribution of their seeds, the fruits are

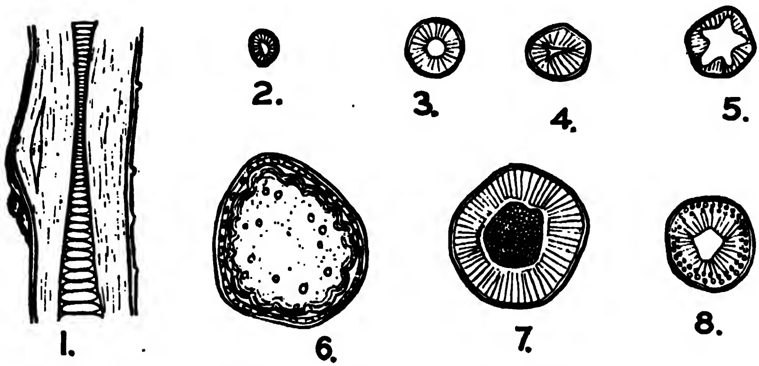


FIG. 225. Types of pith. 1. Black walnut (chambered pith); 2. Birch (semicircular or irregular pith); 3. Elm (circular pith); 4. Black alder (triangular pith); 5. Oak (star-shaped pith); 6. Sumac (large pith); 7. Sassafras (medium-sized pith); 8. Common locust (angular pith). From Illick, *Pennsylvania Trees*, courtesy Penn. Dept. Forests and Waters.

usually attractively colored, fragrant, and provided with desirable and edible fleshy material. These qualities attract the agents of dissemination. The wind-distributed fruits usually lack conspicuousness.

The fruits of dogwood, viburnum, hawthorn, mountain ash, chokecherry, bittersweet, persimmon, etc., are aromatic and brightly colored. They are especially relished by birds.

The mild, edible fruits include black walnut, hickory nut, beechnut, basswood, hazelnut, chinquapin, chestnut, horse chestnut, persimmon, papaw, haw, service or June berry, mulberry, and pine seeds (*Pinyon*).

Twigs. The twigs are the terminal parts of the branches, and they represent the portion of the branch that grew in the last season. The branching may be alternate, opposite, or whorled.

The taste, odor, and color of twigs are sometimes valuable in fixing identities. A single experience with the taste and odor of the black birch, wild cherry, spice bush, or sassafras will substantiate this statement. The red color of the red maple and basswood twig; the green color of the sassafras; and the brown color of the sugar maple twigs are also characteristic and will help in their determination.

Twigs may be rough or smooth according to the number and character of hairs, lenticels, and leaf scars present on them. The pith may also be of value in tree studies by noting its outline and quantity in the cross-section of the twig. In conifers the pith is rather uniform in structure, outline, and color; but in the broad-leaved trees it is quite variable. In most trees the quantity of pith in the twig is small, but in some of them such as the elder, sumac, and sassafras, it is quite large. The outline of pith in cross-section may be five-angled or star-shaped as in the oak, chestnut, and aspen. It is triangular in the alder and in some birches; ovoid in the basswood; circular in the elm; and angular in the locust. In the walnut, butternut, and blackberry, the pith is chambered. The pith of the shad-bush is greenish; in the sugar maple it is white; in the red maple it is pinkish; in the striped maple and sumac it is brown. Some cross-sections are shown in Fig. 225.

Tree Values

There are many benefits derived from trees; anyone could without much effort mention quite a number of tree values. These values may be aesthetic or economic. The beauty of the landscape is most apparent in wooded sections. Without trees a city, a mountain side, a stream, or a home presents a bleak appearance. The shade contributes much to comfort, and the trees themselves provide homes and shelter for birds and other animals. Park and city planning commissions spend considerable sums for planting and taking care of trees which add so much to the beauty and comfort of cities and towns. In addition, trees serve as windbreaks and regulators of temperature and rainfall. They prevent floods and drouths by holding the water in the soil, and they shelter numerous other smaller plants such as ferns and wild flowers which require the moist, shaded conditions provided by trees. The soil is greatly enriched by decaying leaves and branches.

For generations, trees have appealed to the aesthetic side of man; and many beautiful poems and essays have been inspired by

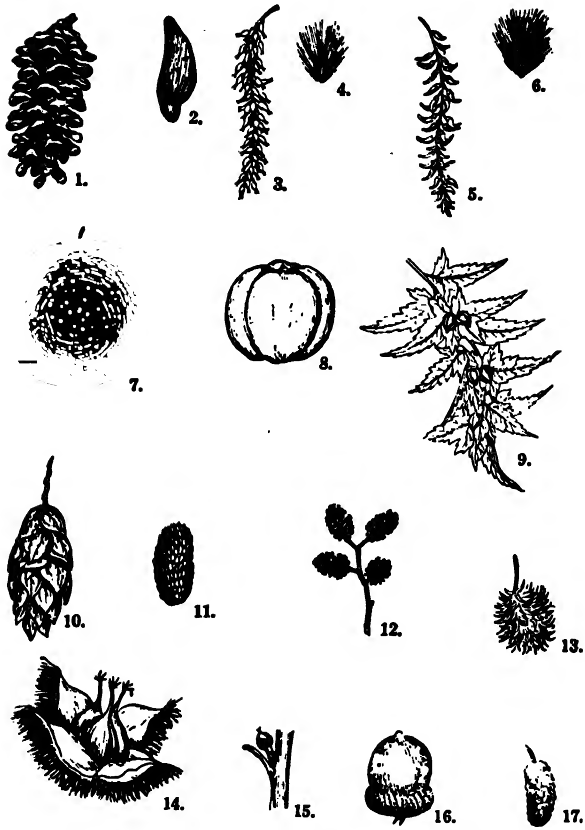


FIG. 226. Types of fruit. 1. White pine (cone); 2. White pine (winged seed); 3. Willow (capsules); 4. Willow (winged seed); 5. Trembling aspen (capsules); 6. Trembling aspen (winged seed); 7. Black walnut (nut with indehiscent husk); 8. Hickory (nut with dehiscent husk); 9. American hornbeam (nut with three-lobed bract); 10. American hop hornbeam (nut inclosed in bladder-like bract); 11. Black birch (membranous strobile); 12. Black alder (woody strobile); 13. Beech (nut with prickly bur); 14. Chestnut (nut with spiny bur); 15. Red oak (immature acorn); 16. Red oak (mature acorn); 17. Red mulberry (aggregate fruit). From Illick, *Pennsylvania Trees*, courtesy Penn. Dept. Forests and Waters.

them. Aside from the more obscure benefits derived from trees, there are material and economic phases which make trees very valuable assets.

Lumber is an almost indispensable necessity, and it is used in a thousand ways. Furniture, houses, matches, pencils, ships, sporting implements, conveyances, and, as someone has said, "almost

everything from cradle to coffin" is made from wood. In addition, artificial silk, paper, rope, dyes, maple sugar, turpentine, gum arabic, pitch, medicines of many kinds, charcoal and other fuel, fruits, nuts, edible roots and bark, alcohol, tannic acid used in curing leather, and a host of other valuable products are obtained from trees. The lumber industry has associated with it numerous other industries such as tanning, furniture-making, paper-making, and many others which provide a livelihood for thousands of persons. Hunting, fishing, camping, swimming, picnicking, and boating are a few of the recreational features made possible by the forest. Without them there would be few birds and wild animals. When we stop to consider the disastrous effects of deforestation, resulting in dust storms, drouths, and floods, we realize just how important trees really are. The floods and famines which have been so serious in China for many years are due largely to deforestation. China was long known as the treeless country, but a vast program of reforestation is in progress at the present time. Without lumber and the other products of trees, life would be considerably less comfortable.

Agents that destroy trees. There are many agencies which destroy trees. Some of them are subtle and invisible, while others are flagrantly perceptible. Wind, snow, floods, and lightning do considerable damage to trees; and not much can be done to prevent these destructive effects. However, there are many agents of destruction that man can control to a considerable extent. Fire is the most rapid destroyer of forests; thousands of acres of forests may be destroyed in a few hours. Even in young forests where the trees average only twenty years in age, the destruction of 200 acres on which there is an average of 150 trees to the acre means the loss of six hundred thousand years of growth when this area is burned. Since the average forest fire consumes forests in which the trees are older and more dense, many millions of years of growth are destroyed in a short time. Man is the worst offender in starting forest fires. Careless campers and picnickers who fail to extinguish their fires, and persons who throw lighted matches, cigarettes, and cigars into the brush or leaves are responsible for most forest fires. Locomotives were at one time responsible for many fires; but in recent years they are equipped with cinder screens, and the right of way is kept cleared of growth so as to minimize the danger of fires.

Injudicious methods of forest removal have been an important factor in destroying woodlands which cannot be replaced within the lives of a generation. This form of destruction has also been controlled in recent years by government supervision and by the study of ways to remove timber with less injury and without completely destroying the forests.

Insects constitute one of the truly great destructive forces over which man has little control, although nursery production and sensible planting are reducing to some extent the ravages. Insects destroy the roots, leaves, stems, flowers, and fruits of trees. The list of destructive species is a long one, and they exact a tremendous toll. Parasitic plants and fungi are also responsible for much damage. The chestnut blight, white pine blister disease, the elm disease, and a host of others are at the present time jeopardizing some of our most valuable species of trees. Quarantine restrictions which prohibit the transportation of trees from one country to another and from one section of the country to another have been established too late to save many species.

Some birds render a little damage, but this is slight. Domestic animals such as cattle, goats, sheep, and hogs; and some wild animals such as deer, porcupines, squirrels, beavers, mice, and rabbits also do considerable damage at times.

While the pioneers failed to comprehend the results of their depredations in the forests, and although there are today a few people who have no respect for the woodlands and their safety, the world is nevertheless forest-minded. The present generation as a whole is desirous of preserving the forests, and the average person is careful not to endanger them. This is shown by the remarkable achievements in reforestation by state and federal governments. The splendid results obtained could not have been accomplished without public coöperation. However, eternal vigilance will be necessary to curb the activities of careless and malicious individuals who have no respect for the rights of others and whose activities may deny to future generations the joys and blessings which forests bestow.

The uses of woods. It has been stated that the uses of wood are many; we shall not attempt to list all of them here. However, these uses may be classified in investigative studies of a most interesting sort. Have you ever wondered what kinds of wood are used in making paper, cigar boxes, furniture, flooring, wagon and auto-

mobile wheels, matches, pencils, and the host of other commodities which we use every day? Cedar chests; orange sticks; walnut, oak, maple, and mahogany furniture; pianos; radio cabinets; and many others are familiar; they suggest the adaptability of the various woods to different uses.

In sports alone many kinds of woods are used in different ways. Baseball bats, oars, and tennis racquets are made of ash, as a rule. Golf clubs generally have hickory handles. Matches are made of white pine which is soft and contains an inflammable pitch. The handles of hoes, rakes, shovels, and forks are made of ash; it is also used for making butter tubs, ladders, and airplane frames. Basswood or linden is used for boxes, drawer slides, wooden ware, picture frames, and musical instruments. Beech is used largely in building operations, especially for flooring; laundry machinery; lard tubs; washboards; and for vehicle parts. Birch, because it takes a fine finish, is used for doors and interior woodwork. It is also used for car construction, musical instruments, novelties, spools, and bobbins. Veneers and oils are obtained from the twigs of birch. The buckeye, on account of its light weight, is used for making packing cases and artificial limbs. Cedar is commonly used for making shingles, although much is used for fence posts and telegraph poles. Red cedar is used for making lead pencils, chests, interior linings of closets, boats, coffins, electrical appliances, and professional instruments. Cigar boxes are made from Spanish cedar, as a rule. Cherry is used extensively for fixtures because it does not warp. It also makes excellent furniture and interior trimmings. Sometimes cherry is used in making cigar boxes. Clock cases, guitars, the backs of hair brushes and clothes brushes, school desks, scientific instruments, and printing and electrotyping accessories are usually made of cherry. Chestnut is one of the finest North American woods. It was formerly used extensively in making cross ties, caskets, tanning extracts, and pianos. Hemlock makes good lumber because it holds nails well. Crates, boxes, refrigerators, and some furniture are made from hemlock. Locust is used for fence posts, cross-arms and insulator pins on telegraph poles, mine timbers, porch flooring, boats, and occasionally furniture. Hickory is a tough, flexible, and resilient wood used in axe and golf club handles, vehicles, single trees and double trees, gymnasium apparatus, canes, artificial limbs; it is also used for smoking meats. Maple is used in millwork, flooring, boxes, furni-

ture, school furniture, shoe heels, and agricultural implements. Oak is used in practically every sort of industry. It is used in rough building operations, box cars, wagons, trucks, office and library furniture, bridges, and cross ties. The bark is used for tanning and for making dyes. Black walnut is becoming scarce, and it is being replaced to some extent by other and sometimes less desirable material. Sewing machine cabinets, fire-arm butts, caskets, furniture, musical instruments, and apparatus are made of walnut when it is available. Airplane propellers were formerly made of oak.

Methods of Tree Study

There are several good manuals for the ready identification of native trees and shrubs. Most of these are listed at the end of this chapter. The student should become thoroughly familiar with the nomenclature used in the keys to the families and species. When all of the terms have been mastered, it is advisable to use the key on some tree which is already known. This will give excellent practice in the use of the key. To many people a key strikes a note of terror, but it is after all the easiest method of determining identities. The families should be learned first. Many of these are familiar to most persons who can invariably indicate whether a tree is an oak, maple, or locust. However, many of the families are unfamiliar; and in some of them, such as the hickory and oak families, the species are very difficult to differentiate. In families such as these there are several outstanding individuals which can always be distinguished even though there are some species which are hard to separate. In the oak family, for instance, the pin oak, the chestnut oak, the white oak, and the laurel oak are fairly characteristic, while some of the other species are difficult to untangle. In many of them it is necessary to have the acorns before the identification can be positive. The oaks and hickories are difficult for even the dendrologists to specify. Since it is virtually impossible to learn all of the species even if they are all accessible, the student should be largely concerned at first with those trees in his immediate neighborhood. However, the identification of these should be made through the use of keys. If this is done, he will have acquired the method of determining identities; and he is then equipped to extend his studies to species outside his immediate realm. Knowing how to determine the

identity of an unknown tree will be valuable to him no matter where he goes.

Trees have a distribution which is characteristic for each species in the same way that animal species have their individual ranges. Magnolias are largely southern in their range, and one would not expect to find them growing in the northern woods. Most species of evergreens are northern, although some of them are found in southern states.

The mountain maple and the striped maple are never found below a certain elevation, and we cannot expect to find them growing along the streets in company with the Norway maple which is largely used as a shade tree in the towns and cities of northeastern United States. The sugar maple may be found in the rural villages, but it cannot tolerate the dust and gases in city districts. Therefore it is advisable to secure from the state bureaus of forestry a list of the trees native to the section. This list will assist in avoiding mistakes in identities. The Federal Forest Service has numerous publications in which the distribution of species throughout the country is shown. The excellent books on trees that are now available will make it possible to readily identify any species.

At Christmastime the market is flooded with evergreens which are used as Christmas trees. Many of these are shipped for great distances, and species foreign to the local section are often imported. The identification of these can be determined by using the suggested references. The identification of the Yule trees is an interesting study.

In attempting the identification of local trees, it is well to map a small section of the campus or town in which trees are to be found. In cities a street or a block in the residential section can be mapped. The map can be a simple one with prominent landmarks indicated so that individual trees can easily be located. This makes an excellent unit for study. All of the trees in the mapped section can be identified in order, and letters or numbers can be used for each species. A small circle can be drawn on the map to show the location of each tree. As each tree is identified, the number representing the species can be written within the circle. The list can then be conveniently checked after all of the identifications are made.

If this plan is not feasible, a list of 25 or more trees can be given; and these can be identified by the student. Sometimes it is possible

for the whole class to make an excursion into a park or into a wooded section, and the identifications can be made as class studies, using the tree guides for determining the species.

It has been suggested that there are many characters by which trees can be identified. All of these characters should be carefully noted and recorded in the field notebook. The type of situation should also be noted. For trees in a wild state the record should indicate whether the tree grew in the open, along the edge of a wood, in the heart of a forest, along a stream, in a swamp or low valley, on a hill, in a ravine, or high on a mountain side. When possible, the direction of exposure should be noted, for sometimes one species grows better with an eastern exposure, while others thrive best under other conditions.

That these observations are of value is indicated by the fact that willows, water beech, and sycamores are usually along the margins of streams, while the chestnuts, striped maple, and white pine are found in elevated areas.

After a number of identifications have been made in a systematic way, the student will soon begin to acquire a "tree sense," and the characteristics of the trees will become meaningful and less difficult.

The records should not only contain a drawing of the outline of the tree as well as notes on the leaf, twig, and bark characters; but it should also include the location of the tree, its size (approximate), and the season. In preparing teaching records, it is advisable to collect specimens of the leaves, flowers, and fruits.

The teaching record should be placed on a sheet of white cardboard with the common names of the tree at the top (Fig. 239). Beneath this, the scientific name should be written and enclosed in parentheses. On the left side of the card a drawing of the outline of the tree can be placed; and on the other side a drawing of the twig should be made. The drawing of the twig is an important item since it indicates the location of the buds, the arrangement of the leaves, the leaf scars, and the rings of growth. In species where the pith characters are prominent, such as the chambered pith of the walnut or the star-shaped pith of the oak, a drawing of a cross, diagonal, or longitudinal section of the twig should be included.

Between the drawings of the outline and the twigs, the outstanding characters of the tree should be written briefly and as simply as possible. All technical terms should be excluded as far as

possible. At the bottom of the card, the pressed leaf or cluster of leaves and the pressed flowers and fruits should be attached. In cases such as the buckeye, in which the fruit is large, it can be attached to the card with glue or string. The thin fruits of maples, elms, and the like will be easy to attach.

Such a record for each local species of tree will be an excellent teaching device, for it can be hung on the wall of the schoolroom where each pupil can see it and read it. The attention of the pupils can be called to the tree, and one species a week may be studied. Each youngster can look for the tree on his way to and from school or in the school yard. Later the tree can be discussed by the class. The writer has found this method successful over a period of nearly 20 years in demonstrating the teaching of trees to children.

For classroom studies, sections of the various trees can be placed in Riker mounts in which they are preserved; and they can be handled by large numbers of students without injury. The teacher should always caution children to exercise extreme care in collecting leaves and other parts of trees. In fact, the children should be taught the importance of avoiding injuries to trees before identification studies are begun.

The method of teaching children about trees will vary somewhat according to the ages of the pupils. However, the author, in directing studies in schools and in demonstrating tree studies in various school systems, has found the following plan to be very successful.

Children love to tell what they know, and the handling of the over-zealous children is one of the real problems in the classroom. Certainly every attempt should be made to avoid suppressing the enthusiasm of the child.

Every youngster can make some contribution to a class study of trees. Rather than submit a list of tree values to the class, it is far better for the teacher, after making her preliminary remarks to the class, to ask the question, "How many of you boys and girls love trees?" (What boy or girl doesn't love trees?) This question can be followed by one such as, "John, why do you like trees?" John gives as his reasons the comfort of the shade, the edible fruits that trees bear, or the fact that birds can build their nests in them. It is surprising how quickly the rest of the class respond; and before long the class will have given a long list of real tree values. The values can be written on the blackboard as they are given; and

when the class has exhausted its supply of tree values, the teacher can then supplement the list with additional ones.

The class interest is usually stimulated by a discussion of this sort, and the teacher can then proceed with the study of other phases of trees suggested in this chapter. The study of woods, the lumbering industry and associated industries, forestry programs, and numerous other phases of tree study should be dealt with.

Such individual studies as "The Trees of History" (Charter Oak, Penn's Treaty Elm, and numerous others), "Trees and Floods," "Drouths and Trees," "Food-Bearing Trees," "Christmas Trees," "What to Plant and Where," "Poems about Trees," "Trees and Birds," and a host of others of a similar nature will prove of value. It is very desirable to require written themes in connection with these studies. A great amount of tree study can be used to motivate the work in history, geography, and English.

In connection with identification studies, the trees should be grouped into units which reveal their most obvious characters. The local trees should be classified under the following headings:

(1) Trees which bloom before they leaf (service berry, elm, redbud, dogwood, linden, willow, hazelnut, Norway maple, most fruit trees)

(2) Trees with winged fruits (elm, ash, maple, ailanthus, linden, pine, hemlock, larch, spruce, birch)

(3) Trees with tufted seeds (poplar, sycamore, catalpa, willow)

(4) Trees with showy flowers (catalpa, buckeye, horse chestnut, magnolia, tulip, dogwood, service berry, redbud, mountain ash, locust, hawthorn, chestnut, wild cherry)

(5) Trees with conspicuous bark (beech, birch, sycamore)

(6) Trees with thorns or spines (locust, hawthorn, wild crabapple, osage orange, holly)

(7) Trees with beautiful autumn foliage (sugar maple, sumac, sweet gum, pin oak)

(8) Trees bearing edible fruits (persimmon, papaw, linden, service berry, mulberry, and almost all nut-bearing trees)

(9) Trees with compound leaves (box elder, locust, ailanthus, buckeye, mountain ash, black walnut, hickory, Kentucky coffee tree)

(10) Trees with prominent leaf scars (ailanthus, buckeye, coffee tree, catalpa, sumac, black walnut)

(11) Evergreen trees (yew, pine, arborvitae, juniper, spruce, hemlock, fir, white cedar).

Since keys to the native trees are available in so many works, it is thought best to mention some of the characters of a few trees in the various families instead of including a key here.

Some common tree families. The evergreens include those trees which have persistent foliage and are therefore green throughout the year. They do not shed their leaves simultaneously as do the deciduous trees. The native evergreens include the pines, hemlock, spruces, yew, arborvitae, fir, cedar, and juniper. The larch is also an evergreen, but it is naked during the winter months.

The pines have long, needle-like leaves which are arranged in clusters on the twig. The clusters include from two to five leaves according to species. The spruces have short, four-sided, needle-like leaves which rest directly and singly upon the twig. The leaves cover the twig on all sides, and they are arranged in spiral formation on the twig.

The hemlock has short, linear, flattened leaves about one-half inch in length. They are arranged spirally on the twig, but they appear to be in two ranks on the sides of the twig. The leaves are not pointed as in the pines and spruces, but they are generally rounded at their tips. There are faint white lines on the underside of the leaf along the midrib. The leaves are shiny above, and dull beneath.

In the cedars and arborvitae the leaves consist of short, rounded, overlapping scales which are compacted on the stem. On young shoots the leaves are awl-like, and they are not recumbent on the stem.

On the larch, the leaves are about an inch long and triangular in cross-section. They occur in clusters on the short, spur-like branches. They are deciduous.

All of the cone-bearing evergreens have a straight, tapering trunk which extends to the top of the tree. The branches grow in whorls about the main stem at definite intervals, the lower ones being longer. All of them extend outward horizontally, thus giving the tree the shape of a cone. All of them are gymnosperms, and the winged seeds are borne in cones; hence the name conifer, or cone-bearing. The magnolias, rhododendron, and laurel are evergreens in which the trunk or stem is deliquescent.

The pines, spruces, hemlocks, cedars, larches, firs, and arborvitae belong to the family *Pinaceae*.

The yew, which has linear, hemlock-like leaves, does not bear

cones; but its fruit is a sessile, red berry containing a single hard seed. The yews belong to the family *Taxaceae.*

The willows comprise a large group of trees and shrubs. They have alternate, narrow, lance-shaped leaves which are rounded at the base. The margins are finely toothed, and heart-shaped stipules are usually present on the petiole at or near the base. The leaves are often downy when young, but smooth when mature. Willows are usually found in moist or wet situations such as in a valley or along a stream. The flowers are borne in catkins, and they usually appear before the leaves. The pistillate and staminate flowers occur on different trees, and the fruits are ovate capsules containing tufted seeds. In form the willows have crooked trunks which deliquesce profusely. The crown is wide, open, and round-topped. The wood is of little commercial importance; but the shoots, which will grow into trees if planted in moist soil, are used in the making of baskets and wicker furniture.

As a group, the willows are difficult to identify into species, but the weeping willow with its drooping branches is unmistakable. The common species in northeastern United States are the black willow, shining willow, glaucous willow, and beaked willow. The crack willow, often found along our streams, is a European species. It is named the crack willow because its branches are brittle and break easily in strong winds. The willows belong to the family *Salicaceae.*

The poplars include the aspens and cottonwoods. The lombardy poplar, the trembling or quaking aspen, the balm of gilead, the silver-leaf poplar, the balsam poplar, and the Carolina poplar are native species in the family. The quaking aspen can be readily identified by the trembling leaves. The lombardy poplar is a straight and very narrow tree with the lateral branches growing upwards and close to the trunk. The Carolina poplar has large, triangular leaves with laterally flattened petioles. The base of the leaf is truncate. The form of this tree is wide at the base, due to the lateral branches growing out horizontally; and it is narrow, tapering towards the top because the higher branches have a slight tendency to grow upwards. The Carolina poplar is a hybrid (*P. nigra* and *P. balsamifera* [?]), and it does not produce seeds. The bark is an ashy gray with deep, longitudinal furrows. The white or silver-leaf poplar, which is an exotic species, is grown frequently for ornamental purposes. It can be distinguished from the other pop-

lars by its lobed leaves which are quite woolly on the underside. The young twigs are also covered with a cottony felt which is easily rubbed off. The flowers occur in catkins about two inches in length on all of the poplars. Pistillate and staminate flowers do not occur on the same tree. The hairy, tufted seeds are enclosed in an oblong capsule.

The balm of gilead is distinguished from the other poplars by having leaves which are heart-shaped at the base. The buds of the poplars are resinous, and in the balsam poplar the sticky material on the buds is fragrant. The poplars also belong to the family *Salicaceae.*

The walnuts include the black walnut, the butternut, and the hickories. The walnuts have pinnately compound leaves with from 11 to 17 leaflets in the butternut and from 12 to 23 leaflets in the black walnut. A terminal leaflet is usually present in the former and absent in the latter. The pith is chambered in both species and is dark brown in the butternut and light brown in the walnut. The fruit of the butternut is elongated, while in the walnut it is round. Both are covered with a hairy and sticky covering which stains readily. The buds of the butternut are larger and more flattened than those of the walnut. The flowers of both species occur in catkins; and both pistillate and staminate flowers occur on the same tree, usually on the same branches. The wood of the two species is used in making many things, but that of the walnut is much heavier. The bark and husks of the fruit are used in making dyes and in tanning. Both nuts are highly delectable. The English walnut is frequently grown as an ornamental tree. Its wood is the prized circassian walnut used extensively in making bedroom furniture. The walnuts belong to the family *Juglandaceae.*

The hickories comprise a large and difficult group to identify as species. The hickories have alternate, compound leaves; but the leaflets occur alternately on the petiole. They number from five to 11 according to species. The pistillate flowers occur in spike-like clusters of from two to six. The staminate flowers occur in clusters of three catkins. The nuts are variable ranging from roundish to almost cylindrical, and they are covered with four valved husks which usually split open when the fruit is ripe. The wood of most of the hickories is quite valuable, with the exception of the bitternut hickory; and several of the nuts are excellent. The most conspicuous of the hickories is the shagbark hickory on which the

old bark is shed in long strips which become loose at the bottom and peel upwards. The extending loose ends give the tree a shaggy appearance.

The shagbark or shellbark, mockernut, pignut, and bitternut hickories are the most common species. They also belong to the walnut family *Juglandaceae.*

The birch family includes some of our most beautiful trees. All of the birches have simple, ovate, alternate leaves with sharply toothed margins and pointed tips, or apices. The birches have smooth bark which peels off horizontally in thin, paper-like strips. The lenticels are elongated horizontally. All of the birches bear flowers in catkins which are either pistillate or staminate, and both kinds are found on the same tree. The common species are the paper birch, which has a creamy to white bark which peels off in narrow strips tinged with yellow along their sides; the yellow birch, which can be readily distinguished by its yellow, paper-like bark; the red birch, which has a reddish or cinnamon brown bark; the gray birch, which has a white bark that is never renewed when it peels. The gray birch may be easily confused with the European white birch. The black birch has a bark resembling that of the cherry. The bark of the black birch has a sweet aroma resembling wintergreen, when scratched; that on young twigs is edible and pleasant to chew. The fruit of the birch consists usually of a single, winged seed, although the seeds sometimes occur in small clusters or strobiles. The birches belong to the family *Betulaceae.*

Other members of the birch family lack the smooth bark which characterizes the birches themselves. They include:

The American hop hornbeam (*Ostrya virginiana*) which is a tree attaining a height of from 20 to 30 feet. The leaves are simple, alternate, ovate-oblong, and from three to five inches long. The apex is acute, and the margin is doubly serrate. The base is heart-shaped or wedge-shaped. The flowers are borne in catkins, and each of the pistillate flowers is enclosed in a bladder-like bract. Staminate catkins persist throughout the winter. The seeds are small nuts enclosed in a bladder, at the base of which are irritating hairs. The bark is a thin, grayish brown and peels off in narrow scales. The species is also known as ironwood or deer wood. The American hornbeam (*Carpinus caroliniana*) resembles the hop hornbeam except that the staminate flowers are short, and the fruits are not enclosed in the swollen bladders. The bark is rather

smooth and the trunk is angled or fluted. It occurs in moist soil, usually near a stream.

The smooth alder (*Alnus rugosa*) is a related common tree which is more like a shrub. It is usually about ten feet high. The leaves are alternate, simple, thick, and blunt or rounded at the tips. The base is wedge-shaped, and the margin is finely and regularly serrate. The shape is more nearly ovate than in the hornbeam. The catkins develop late and remain dormant throughout the winter. The fruit is an orbicular, cone-like cluster containing small nuts.

The hazelnut (*Corylus americana*) is a common shrub with simple, alternate leaves with serrated margins. The leaves are obovate with heart-shaped base and pointed tip. They are slightly hairy beneath. The flowers occur in catkins before the leaves appear. The fruit is an edible, ovoid nut which is enclosed in leafy bracts which resemble the tied end of a paper bag. In the beaked hazelnut (*Corylus rostrata*) the bracts extend considerably beyond the nut. All of the above trees belong to the birch family *Betulaceae*.

The beech (*Fagus grandifolia*) is one of the commonest trees in the northeastern states. Its light, silvery gray, smooth bark seems to be an irresistible temptation to young lovers who succumb to the urge to carve their initials within a heart on it. The leaves are alternate, simple, pinnately veined, with coarsely toothed margins. The flowers are inconspicuous. The fruit is a stalked, prickly, four-valved bur containing shining, triangular, pale brown, edible nuts which are relished by bears and grouse.

The chestnut (*Castanea dentata*) is a larger member of the same family with conspicuous clusters of white flowers that are almost aments or catkins. The fruit is a very spiny bur containing from two to five nuts. The bur opens late in October, dropping the nuts to the ground. The chestnut is one of America's finest trees, but the chestnut blight has almost exterminated it in the eastern states. Both the chestnut and the beech belong to the family *Fagaceae*.

The oaks constitute one of the largest groups of trees in the United States. They belong to the beech family. The species are widely distributed, although quite a number of them occur in the northeastern states. The leaves are simple, alternate, with wavy or deeply cut margins. The flowers are borne in hairy aments, and the fruit consists of clusters of the well-known acorns. In many of the oaks the leaves are persistent and remain on the tree all winter. The common species of oaks are: white (*Quercus alba*);

post (*Q. stellata*); bur (*Q. macrocarpa*); swamp white (*Q. bicolor*); yellow (*Q. muhlenbergii*); chestnut (*Q. prinus*); red (*Q. rubra*); pin (*Q. palustris*); black (*Q. velutina*); scrub (*Q. ilicifolia*); laurel (*Q. imbricaria*); and willow oak (*Q. phellos*).

The elms include the slippery elm (*Ulmus fulva*); the American elm (*U. americana*); and the European elm (*U. campestris*). All of them have simple, alternate, pinnately veined leaves with doubly toothed margins. The bases of the leaves are unequal. The leaves have a heavy texture, and some of them are rough on the upper surface. The fruit is a samara consisting of a flat seed surrounded by a wing. The general form of the tree is wedge-shaped; and the bark is thick and rough, with longitudinal fissures. The slippery elm has a fragrant inner bark, and the leaves are rough above. In the American elm the leaves are smooth to somewhat rough on the upper surface, and the fruit is hairy around the margin. The elms belong to the family *Urticaceae*.

The hackberry (*Celtis occidentalis*) is another member of the elm family. It is a small tree with a short trunk. The leaves are alternate, simple, ovate, and obliquely rounded at the base. The apex of the leaf is acutely pointed. The margin is serrated except near the base where it is entire. The fruit is a dark purple, berry-like drupe tipped with a persistent style. The hackberry is a hardy tree that will grow in most unfavorable situations.

The osage orange or hedge apple (*Maclura pomifera*) was formerly used much more extensively as a hedge around fields. Its simple, alternate leaves are ovate in outline with the margins entire. The base is wedge-shaped, and the apex or tip is rather acute. The upper surface is dark, and the underside is pale green. The young twigs are greenish and pubescent and contain yellow pith. The younger branches are armed with stout spines. The flowers appear in June. The staminate flowers occur in racemes on long, slender, drooping stalks; and the pistillate flowers occur in dense, rounded heads with short stalks. The fruit is a large mass of many small drupes closely fused together. It is about the size of a large orange and resembles a green orange in appearance.

The red mulberry (*Morus rubra*) can be easily distinguished by the several types of leaves found on it. The leaves are simple, alternate, ovate, with three principal veins except in lobed forms, and with serrated margins. The base is cordate, and the apex is acute. The leaves may be mitten-shaped, or they may have from

three to five lobes. The flowers, which appear in May or June, are borne in dense spikes, about an inch in length. The fruit is compound or aggregate, composed of many small drupes. It is dark purple when ripe and is edible.

The magnolias are largely southern, although several species are native to the northeastern states. They are among the most beautiful of all trees. Their large, broad, thick, shining, dark green leaves resemble tropical foliage. The leaves have entire margins; and they are simple, alternate, and oval, or broadly lanceolate in shape. The flowers are large, globular, and solitary; and both the calyx and corolla are white, although they may be tinged with yellow as in the cucumber tree. The fruit is an erect, fleshy cone of variable length, usually red in color. The seeds are red. The common species are the laurel magnolia (*Magnolia virginiana*); cucumber tree (*M. acuminata*); and umbrella tree (*M. tripetala*). They belong to the family *Magnoliaceae*.

The magnolia family also includes one of the East's most popular trees, the tulip poplar or tulip tree (*Liriodendron tulipifera*). The leaves are peculiarly shaped, almost resembling a lyre in general outline. They are really broadly ovate, being wider near the base and truncated at the apex. There are two apical and from two to four basal lobes. The color is bright green above and paler beneath. The petioles are long and very slender. The flowers are large, greenish-yellow, and cup-shaped, with three reflexed sepals and six converging petals. The fruit is a spiny-looking, sharply tapering, erect, and pointed cone consisting of long carpels. In the bases of the carpels the hard seeds are contained. The cone is usually persistent, which aids in identifying the tree in winter. The species is known also as the yellow poplar, popple, and whitewood. The twigs contain large pith which is often divided by stone cells.

The papaw (*Asimina triloba*) is a southern tree with long, simple, alternate, obovate-lanceolate leaves of heavy texture. The leaf is narrow at the base and widens toward the apex, coming suddenly to a point. The flowers are borne along the twigs. They are green at first, turning to a reddish-purple later on. The fruit is large, brownish black, fleshy, cylindrical, and banana-like. The inner pulp is bright orange containing many dark brown, flattened seeds. The papaw belongs to the custard apple family, *Anonaceae*.

The sassafras (*Sassafras variifolium*) is a common tree with several kinds of leaves on the younger plants. The leaves are

simple, alternate, and obovate, with entire margins, although entire, two-lobed, three-lobed, and five-lobed leaves may occur on the same branch. The twigs are slender, greenish or reddish, hairy, brittle, and aromatic. The pith is large and white. The fruit is borne in clusters on bright red stems and consists of a small, rounded, dark blue drupe which rests in an enlarged calyx. The sassafras belongs to the family *Lauraceae.*

The witch hazel (*Hamamelis virginiana*) is a small tree with simple, alternate, oval leaves from four to six inches long. They are rounded or acute at the apex and oblique at the base. They are smoothly dentate on the margins, and the midrib is prominent. The bright yellow flowers occur late in the fall in small axillary clusters. The flower buds are spherical. The fruit is a yellowish-brown, woody pod composed of two cells which contain small, black, shining seeds which are violently discharged when ripe. The witch hazel belongs to the family *Hamamelidaceae.*

The sweet gum or liquidambar (*Liquidambar styraciflua*) is another member of the witch hazel family. Its outline is rather ovoid, due to the fact that the main trunk extends unbroken to the top of the tree. The leaves are star-shaped and therefore easy to identify. The flowers are of two types. The staminate flowers are green and borne in terminal racemes, while the pistillate flowers occur in dense heads borne on long stalks. The fruit is a long-stalked, spherical head composed of numerous capsules, the tips of which give the fruit a spiny appearance. The fruit is rather persistent. The species has a wide range.

The wild plum, the wild black cherry, the fire cherry, and the chokecherry belong to the rose family, *Rosaceae*, and to the genus *Prunus.* The plum (*P. americana*) can be distinguished from the others by its fruit and by the absence of the terminal bud. It resembles the cultivated fruit in shape, bark, and flowers. The fruit is subglobose, red, and contains a flattened stone seed.

The fire cherry (*P. pennsylvanica*) can be distinguished from the other cherries by the flowers which are borne in umbels and by its slender twigs which bear clusters of terminal buds. The bark has horizontal, elongated, orange-colored lenticels which the other species lack. The fruit is a small, bright red, juicy drupe.

The wild black cherry (*P. serotina*) bears its white flowers in racemes, and the fruit is a purplish black. The species is larger than the other cherries, and its bark is dark and rough for a cherry.

The chokecherry (*P. virginiana*) also bears its flowers in racemes. The fruit is dark red, and the bark is much smoother than that of the black cherry. The leaves are also thinner and more finely serrate. The tree is small, rarely attaining a height of 30 feet.

The hawthorns, or thorn apples, belong to the rose family also. The scarlet hawthorn (*Crataegus coccinea*) or red haws is a very common tree in neglected pasture fields. The leaves are simple, broadly ovate, pubescent, and with from five to nine small lobes on the apical half of the margin which is finely serrate. The flowers are arranged in corymbs containing a few flowers, and they are borne on hairy stalks. The flowers are white in color. The fruit is a roundish pome not unlike the fruit of the rose in appearance. It is slightly pubescent and edible.

The American mountain ash (*Pyrus americana*) is one of the most beautiful trees in America. It has alternate compound leaves with from 13 to 17 sessile, opposite leaflets. A terminal leaflet is present. The leaflets are lanceolate, pointed, and finely serrate. The white, perfect flowers are arranged in cymes about three or four inches wide; and the fruit consists of clusters of bright red berries, about the size of a pea. The bark is thin and smooth; and the twigs are reddish brown with conspicuous, light-colored lenticels. The pointed, sticky, alternate buds are also characteristic. It is usually found on rocky hillsides and in boggy uplands (northern Pennsylvania). It belongs to the family *Rosaceae*.

The shadbush or service berry or June berry (*Amelanchier canadensis*) has simple, alternate, ovate leaves with serrated margins. The flowers occur in dropping racemes, and they appear very early in the spring before the other trees bloom. The purplish, berry-like fruit is borne on racemes and is edible. It also belongs to the family *Rosaceae*.

The sycamore, buttonwood, or plane tree (*Platanus occidentalis*) can be readily identified by its yellowish bark which is shed in large, rounded, brownish scales which give it a mottled appearance. The leaves are simple, alternate, ovate, and have from three to five lobes. The flowers appear in dense heads which mature into the familiar drooping balls. The balls or heads are composed of many hairy seeds. The sycamore is most commonly found bordering streams. It attains a huge size, and its form is somewhat irregular. The London plane tree (*Platanus acerifolia*) is the one most commonly planted along streets because it is regular in form; the head

is high and rounded; and it does not attain the great size of the native species. The London plane tree is a hybrid between *P. occidentalis* and *P. orientalis.* It can tolerate conditions of less moisture which the native sycamore cannot endure.

The Kentucky coffee tree (*Gymnocladus dioica*) can easily be identified by its alternate, doubly compound leaves which may be as much as three feet in length. Each branch may bear from seven to thirteen ovate leaflets which occur in pairs. The greenish-white, staminate flowers are borne in raceme-like corymbs; and the pistillate flowers occur in terminal racemes. The fruit is a large, broad, and flat pod containing from six to nine large, broad, flat, dark brown seeds. The fruits are rather persistent. It belongs to the family *Leguminosae.*

The honey locust (*Gleditsia triacanthos*) has alternate, singly- or doubly-compound leaves with flattened petioles. The leaflets are lanceolate-oblong and slightly serrate on the margins. The leaflets occur in pairs, and there is no terminal leaflet. The white flowers are very fragrant; they are borne in racemes, the pistillate racemes being longer than the staminate. The fruit is a long slender pod which contains many flat, oval, brown seeds. The pods are frequently twisted. The twigs are irregular and stout; and they have sharp, stout thorns which are frequently branched. The bark is often covered with large thorns. The black locust (*Robinia pseudo-Acacia*) is another native species with two thorns at the base of the leaf. The locusts belong to the family *Leguminosae.*

The redbud, wild pea, or Judas tree (*Cercis canadensis*) is one of a group of trees and shrubs which are widely distributed. The redbud attains a height of 20 feet, and the branches are somewhat upright. The leaves are simple, alternate, rounded, or heart-shaped, with from five to seven conspicuous veins. They have entire margins and measure about four inches in length. The flowers, like those of the locusts, are papilionaceous or pea-like. They are bright red in color and occur in clusters of five or more. The fruit is a small, light brown, short-stalked pod containing six broadly ovate, flattened, light brown seeds. The redbud belongs to the family *Leguminosae.*

The poison sumac (*Rhus vernix*) is small and shrub-like. It has smooth, thin, streaked, grayish bark with horizontally elongated lenticels. The twigs are stout, orange-brown, with raised lenticels. A watery fluid exudes from a cut twig, and this turns yellow upon

exposure to the air. The leaves are alternate, compound, with from seven to thirteen leaflets, a terminal one usually being present. The leaflets are obovate, entire, and shining green above; they occur in pairs. They are about four inches long. The flowers occur in long, drooping panicles. The tree is dioecious. The fruit consists of small, glossy, ivory- or white-colored drupes arranged in loose, grape-like clusters. The species, which is also known as poison oak or swamp sumac, is very poisonous to most people and should be avoided. It belongs to the family *Anacardiaceae*, in which the cashew and poison ivy are included.

The upland sumacs include three principal species: the staghorn sumac (*Rhus typhina*); the dwarf sumac (*Rhus copallina*); and the smooth sumac (*Rhus glabra*). All are irregular in form with rough, downy twigs. The twigs contain a milky fluid which turns black on exposure. The leaves are alternate compound with a stout wingless petiole. The staghorn has from 11 to 31 oblong, sessile leaflets in pairs and with a terminal leaflet. The margins of the leaflets are serrated, and the bases are heart-shaped. The yellowish-green flowers are borne in very dense panicles. The fruit is produced in compact, upright, cone-like clusters which are deep red in color. The single fruit is a spherical drupe covered with red hairs. Sumacs with red fruit are not poisonous.

The dwarf sumac is a small shrub with irregular, hairy twigs. The twigs do not remain hairy as in the staghorn, however. The leaves are seldom more than 11 inches long, and they have from 9 to 21 leaflets. The margin of the leaflets is usually entire. The petiole of the leaf is winged, which is not the case with the staghorn sumac. The flowers and fruit are somewhat similar to those of the staghorn sumac. The winged petiole, the entire margins of the leaflets, and the watery juice in the twigs, combined with its small size, distinguish the dwarf sumac from the staghorn and the smooth sumac. The sumacs belong to the family *Anacardiaceae*.

The ailanthus (*Ailanthus glandulosa*), or tree of heaven, is of oriental origin. It is found growing extensively in cities in places where other trees will not grow. Mature trees are very large with stout branches and few twigs. The twigs are stout, clumsy, yellowish-green, and velvety. The leaf scars are prominent. The leaves are alternate, compound, and sometimes three feet long. The leaflets are ovate-lanceolate and number from 11 to 41. They are acuminate at the tips and truncate or heart-shaped at the base.

The margins are mostly entire, but a few rounded teeth are usually present near the base. On the undersides of these teeth, distinct glands are present.

The flowers are small, greenish, and arranged in terminal panicles. The fruit consists of clusters of twisted, oblong wings. In the center of each wing there is a small seed. Only the female trees bear fruit, and the clusters of winged seeds persist throughout the winter. The ailanthus belongs to the family *Simarubaceae.*

The holly has two common representatives in the East. The American holly (*Ilex opaca*) is the common Christmas variety. It can be readily distinguished by its bright red fruits and by its spiny leaves. The large-leaved holly (*Ilex monticola*) has simple, alternate, ovate leaves with serrated margins; and they lack the spines which characterize the American holly. The flowers are white, and they are borne in small clusters. The fruit is a bright red nutlet. The hollies belong to the family *Aquifoliaceae.*

The maples have simple, opposite leaves as a rule, although a few of them are compound. The family characters of the maples are extremely diverse. The leaves may be simple or compound, large or small, smooth or hairy. The twigs may be green, brown, or reddish. The flowers may occur in small lateral clusters or terminal racemes; and they may appear before or after the leaves. The color of the flowers may be yellow, green, or red. The maples agree more closely in the fruit, which is a key, shaped like the wing of an insect. The seed is located in the base of the wing. The keys occur doubly; and although they vary greatly in the divergence of the fruits, the winged seed of the maples is a positive character of identification. The common species are red maple (*Acer rubrum*); striped maple (*Acer pennsylvanicum*), which occurs only in mountainous sections; mountain maple (*Acer spicatum*), which bears its flowers in terminal racemes; sugar maple (*Acer saccharum*) with thin bright leaves that are broader than long; silver maple (*Acer saccharinum*) which has a cylindrical outline, gray twigs, deep-cut leaves which are pale on the back, and drooping lateral branches which turn up at the ends, leaving a cinnamon brown when torn off; Norway maple (*Acer platanoides*) which is grown extensively for shade purposes. It has a rounded outline, dark green leaves which are almost the same color on both sides, and a leaf petiole which contains a characteristic acrid milky sap. The box elder, or ash-leaved maple (*Acer negundo*) has opposite,

pinnately compound leaves with from three to five leaflets. The maples belong to the family *Aceraceae.*

The Hercules club (*Aralia spinosa*) is a member of the ginseng family. It has alternate, singly- or doubly-compound leaves which may be almost three feet long and two feet wide. The leaflets are ovate, three inches long, sharp-pointed, and serrated on the margins. The base of the petiole almost encircles the twig. The flowers are creamy white and occur in panicled umbles which may be three feet long. The fruit is an ovoid black berry which is five-angled. The species is also known as the Angelica tree. It belongs to the family *Araliaceae.*

The buckeyes, which are commonly called horse chestnuts, have palmately compound leaves with from five to seven leaflets. The leaves are opposite, and the leaf scars are prominent characters of identification. The twigs are somewhat irregular. The white flowers are very conspicuous, and they are borne in upright panicles. The fruit is a large brown nut enclosed in a rough capsule. In the fetid buckeye (*Aesculus glabra*) the fruit is rough and prickly, but in the sweet buckeye (*Aesculus octandra*) the fruit is smooth. The buckeyes belong to the family *Sapindaceae* which includes the horse chestnut (*Aesculus hippocastanum*) and the western soapberry.

The linden or basswood (*Tilia americana*) is a large tree with alternate, simple, orbicular to cordate leaves which are broad, sharp-pointed, and heart-shaped at the base The margins are coarsely toothed. The side of the leaf next to the branch is larger than the other side. The greenish-white flowers appear early, and they occur in cymose clusters. The fruits are small nuts borne in small clusters to which there is attached an oblong, leaf-like bract. The attachment of the fruit cluster is on the middle of the bract. Another mountainous species, the white basswood (*Tilia heterophyla*), occurs in the eastern states. It is the dominant species in the South. The linden belongs to the family *Tiliaceae.*

The dogwoods include two principal wild species. The flowering dogwood (*Cornus florida*) is abundant, and in the early spring its clusters of greenish flowers are among the earliest to appear. The flower cluster is surrounded by four large white or pinkish bracts which are often mistaken for petals. The flowers appear before the leaves. The leaves are opposite, simple, and clustered toward the end of the branch. They are ovate, pointed at the apex, and wedge-

shaped at the base. The margins are entire or wavy. The fruit consists of red ovoid drupes borne in upright clusters; each drupe contains a grooved stone seed.

The alternate-leaved dogwood (*Cornus alternifolia*) has cream-colored flowers, and the fruits are more nearly spherical. The dogwoods belong to the family *Cornaceae.*

The black gum (*Nyssa sylvatica*), tupelo, or sour gum, is a medium-sized tree with scaly bark which in old trees resembles the skin of an alligator. The scales are quadrangular or rectangular, as a rule. The leaves are simple, alternate, acute at the apex and wedge-shaped at the base. The margin is entire and slightly thickened. The autumn color is red. It is almost the first tree to take on autumn coloration. The leaf scars are broadly crescent-shaped with three single or three groups of bundles. The flowers are borne on slender downy stalks. The pistillate flowers occur in open, few-flowered clusters; and the staminate flowers occur in dense, many-flowered heads. The fruit is an ovoid dark-blue berry or drupe with from one to three in a cluster. The tupelo belongs to the family *Cornaceae.*

Mountain laurel (*Kalmia latifolia*) is a shrub with simple, oblong, entire-margined, thick, leathery, dark-green leaves. The leaves are shiny above and yellowish-green beneath. The leaves are acute at the apex and wedge-shaped at the base. The flowers are angular cups with purple spots in the angles of the corolla. The ten anthers are sunk into ten pouches in the limb of the corolla. The stamens are attached by their filaments to these purple areas. The flowers are borne in dense, many-flowered corymbs. The fruit is a roundish, woody, and hairy capsule containing many seeds. The fruit is conspicuous only because the calyx and style persist on the fruits. The laurel is found only in shady places, and its foliage is supposed to be poisonous to stock. The laurel belongs to the Heath family, *Ericaceae,* which includes mountain laurel, sheep laurel, huckleberries, cranberries, rhododendron, and other common shrubs.

The sour wood or sorrel tree (*Oxydendron arboreum*) is also known as the lily-of-the-valley tree. The species is not abundant or widely distributed. Its leaves are simple, alternate, narrowly oblong, with serrated margins. They are smooth, acute at the apex, wedge-shaped at the base, and from five to seven inches long. They resemble the leaves of the peach. The white, bell-shaped

flowers are borne in racemes from six to eight inches long. The flowers greatly resemble the lily-of-the-valley. The fruit is a five-sided, five-valved capsule terminated by a persistent style. The sour wood belongs to the family *Ericaceae.*

The persimmon (*Diospyros virginiana*) is a small tree with thick, dark, shining green, alternate, oval leaves which are acute at the apex and wedge-shaped at the base. They are from four to six inches long and hairy on the undersides. The small, white flowers are borne in two to three flowered cymes (staminate), and the pistillate flowers are solitary. The fruit is a juicy, spherical, orange-colored berry containing from one to eight seeds. The green fruit is very astringent and puckers the mouth, but it is luscious when fully ripened. It is about the size of a large hickory nut. Cultivated persimmons, about the size of a large plum or larger, are sold at fruit stands. The persimmon belongs to the Ebony family, *Ebenaceae,* which has representatives in many parts of the world, especially in tropical regions.

The catalpa (*Catalpa bignonioides*) is a large tree with large cordate or heart-shaped leaves which are borne in whorls, usually of three. The flowers are white with purplish spots on their inner surfaces. The flowers occur in large, erect clusters which are crowded panicles. The fruit is a long, cylindrical, bean-like pod or capsule which contains numerous flattened and winged seeds. The wings surround the seeds, and they are fringed at their ends. The pod is often called an "Indian toby," cigar, or bean. The species belongs to the family *Bignoniaceae* or Bignonia family.

The ashes belong to the olive family, *Oleaceae,* which includes the lilac, forsythia, privet, and olive. The ashes have opposite, pinnately compound leaves. The leaflets occur in pairs, and a terminal leaflet is present. In some species the leaflets are sessile, while in others they are borne on stalks. The twigs and branchlets are opposite and slightly flattened at their point of attachment. The flowers occur in dense purple clusters, the pistillate clusters being much more open and in panicles. The flowers appear before the leaves. The fruit of the ashes is a winged samara, at one end of which is located a narrow, elongated seed. The wing is elongated and tapering abruptly. The fruits are borne in dense clusters. There are three principal species which are used extensively for shade and ornamental purposes. The wood of all of them is valuable. The ashes belong to the genus *Fraxinus,* with the white ash

(*F. americana*), red ash (*F. pennsylvanica*), and black ash (*F. nigra*) widely distributed.

The sweet viburnum (*Viburnum lentago*) is a shrub or small tree with simple, opposite, ovate, sharp-pointed leaves about three inches long. They are bright green with conspicuous veins and sharply serrated margins. The leaf petiole is grooved and often winged. The buds are long, slender, reddish-brown, and covered by two rough scales. The bark of the tree has a disagreeable odor. The flowers are small, white, perfect, sessile, and borne in conspicuous, terminal cymes from three to five inches broad. The fruit is a black or dark blue, elliptical, juicy drupe containing a flat, oval seed. The fruits are borne in clusters, and they are relished by grouse and other birds. The viburnum is one of a large family—the honeysuckle family, *Caprifoliaceae*. The black haw (*Viburnum prunifolium*) is another native species.

BIBLIOGRAPHY

Trees

Apgar, A. C., *Trees of the Northern United States and Canada*. American Book Co., 1892.

——, *Ornamental Shrubs of the United States*. American Book Co., 1910.

Blakeslee, A. F., and Jarvis, C. D., *Trees in Winter; Their Study and Identification*. Macmillan, 1931.

Britton, N. L., *North American Trees*. Henry Holt, 1908.

Deam, C. C., *Trees of Indiana*. Pub. 13, Ind. Dept. Conservation, Indianapolis, 1921.

Finlay, Margaret C., *Our American Maples*. Published by the author. Allenhurst, N. J., 1934.

Frothingham, E. H., *The Northern Hardwood Forest, Its Composition, Growth, and Management*. U. S. Dept. Agric. Bull. 285, 1915.

Harris, J. T., *Wood-using Industries of New York*. N. Y. State College of Forestry, Series 14, No. 2, 1913.

Harris, J. T., et al., *Wood Utilization Directory of New York*. Tech. Pub. No. 6, Vol. 16, N. Y. State College of Forestry, 1917.

Hough, R. B., *Handbook of the Trees of the Northern States and Canada East of the Rocky Mountains*. Published by the author, Lowville, N. Y., 1907.

Illick, J. S., *Pennsylvania Trees*. Bull. 11, Pa. Dept. Forests and Waters, 1928.

Keeler, Harriet, *Our Northern Shrubs and How to Identify Them*. Scribner, 1903.

Keeler, Harriet, *Our Native Trees and How to Identify Them.* Scribner, 1929.
King, Julius, *Talking Leaves.* Harter Pub. Co., 1934.
Lamb, G. N., *A Calendar of the Leafing, Flowering, and Seeding of the Common Trees of the Eastern United States.* Monthly Weather Review, Suppl. 2, 1915.
Lennion, J. J., *Studies of Trees.* John Wiley and Sons, 1917.
Lounsberry, Alice, *Guide to Trees.* Stokes, 1900.
MacDougal, D. T., *Growth in Trees.* Carneg. Inst. Pub. 307, 1921.
Matthews, Schuyler, *Familiar Trees and Their Leaves.* Appleton, 1911.
——, *Fieldbook of Trees and Shrubs.* Putnam, 1915.
Mattoon, W. R., *The Southern Cypress.* U. S. Forest Service Bull. 272, 1915.
——, *Common Forest Trees of Georgia.* Ga. State College of Agric., Athens, 1923.
——, *Common Forest Trees of Kentucky.* Ky. Dept. Agric., 1923.
——, *Common Forest Trees of South Carolina.* Clemson Coll. Ext. Serv. Bull. 55, 1923.
——, *Forest Trees of the District of Columbia.* Am. Forestry Assoc., Washington, 1923.
——, *Common Forest Trees of Florida.* Fla. Forestry Assn., 1925.
——, *Forest Trees of Connecticut.* Conn. State Park and Forest Comm., 1929.
——, *Forest Trees of Minnesota.* U. of Minn. Ag. Dept. Pamp. 17, 1930.
McFarland, J. H., *Getting Acquainted with the Trees.* Macmillan, 1904.
Mulford, F. L., *Trees for Town and City Streets.* Farmers' Bull. 1208, U. S. Dept. Agric., 1922.
Parkhurst, H. E., *Trees, Shrubs, and Vines of the Northeastern United States.* Scribner, 1903.
Perry, G. S., *The Common Trees and Shrubs of Pennsylvania.* Bull. 33, Pa. Dept. Forests and Waters, 1932.
Peterson, Maud G., *How to Know Wild Fruits.* Macmillan, 1905.
Pinchot, Gifford, *The Big Trees of California.* U. S. Dept. Agric. Bull. 28, 1900.
Pythian, J. E., *Trees in Nature, Myth, and Art.* G. W. Jacobs, 1907.
Record, S. J., *Timbers of North America.* John Wiley and Sons, 1934.
Rehder, Alfred, *Manual of Cultivated Trees and Shrubs.* Macmillan, 1934.
Robinson, B. L., and Fernald, N. L., *Gray's New Manual of Botany,* 7th edition. American Book Co., 1908.
Rogers, J. E., *The Tree Book.* Doubleday Page, 1905.
——, *Trees Worth Knowing.* Little Nature Library. Doubleday Page, 1922.
Sargent, C. S., *The Silva of North America: A Description of the Trees*

That Grow Naturally in North America, Exclusive of Mexico, Vols. 1–14. Houghton Mifflin, 1891 to 1902.

Sargent, C. S., *Manual of the Trees of North America (Exclusive of Mexico)*. Houghton Mifflin, 1922.

Stone, G. E., *Shade Trees, Characteristics, Adaptation, Diseases, and Care.* Bull. 170, Amherst Agric. Exp. Sta., 1916.

Stone, G. L., and Ficket, M. Grace, *Trees in Prose and Poetry*. Ginn, 1902.

Sudworth, G. B., *Miscellaneous Conifers of Rocky Mountains Region.* Bull. No. 680, U. S. Dept. Agric., 1918.

Tillotson, C. R., *The Care and Development of the Woodlot.* Farmers' Bull. 711, U. S. Dept. Agric., 1916.

——, *Growing and Planting Hardwood Seedlings on the Farm.* Farmers' Bull. 1123, U. S. Dept. Agric., 1921.

PART IV

METHODS OF STUDY

CHAPTER XXII

PRACTICAL SUGGESTIONS FOR STUDY

It has been implied throughout this entire text that field work and practical observations constitute an essential requisite in the study of nature. Bookish information and theoretical deductions arrived at from plain reading are somewhat antiquated methods of learning. Modern science has advanced rapidly because of its practical aspects. The scientist of today is "from Missouri"; and only visible, tangible evidence will convince him of the authenticity of, or justification for, any conclusions that may be advanced in support of a scientific interpretation.

Therefore follow the advice of a great teacher, Louis Agassiz, who said, "Study nature, not books"; and see all you can outdoors. Books will, however, prepare you for making observations and they will help you to interpret what you see. Manuals for the identification of species are, of course necessary.

But there are certain procedures which should be followed in making studies in the field. A knowledge of how to go about making these studies so as to get the most out of them is essential. The places to search, the equipment needed, the kinds of observations to make, the collection and preservation of material, and the kinds of records to keep, are all important.

Field Work

Planning the field trip. Too often the nature trip degenerates into a hike, and the class boasts of having covered so many miles on their expedition. When a student indicates that his field trip for the day took him over miles of countryside, it is a sure sign that his field studies were anything but thorough. The real naturalist cannot get very far on a single field trip, for rapid progress means that many things are being overlooked.

It is always advisable to have a well-defined objective in field work. That is, you should plan definitely just what you want to do on the trip before it is made. At first, general collecting trips are valuable because the student learns how to use his net, and he

also gets a general idea as to where things are to be found. The classification of this material into phyla, classes, and orders should follow the field exercise. In the laboratory study of this material, the methods of mounting, labeling, and displaying specimens should be taught and practiced.

Later field studies are much more efficient if definite types of situations are studied. The life on a sandy beach; the life in a pond; the animals or the plants in an open field; the animals or plants of a marsh; the dead log association; these and many others provide well-defined and specific habitats, each with its coterie of plants and animals in an association that is more or less unique.

In such studies both the plants and animals can be studied simultaneously or independently, as desired. The value of habitat and association studies cannot be overestimated. Activities of animals observed or collected should be carefully recorded. If field studies are made by a group, the leader should have a whistle to keep the members from wandering afar or to call the class together quickly in case someone discovers something which everyone should see. Nests of birds, ant or termite colonies, a litter of young animals, or any other things of similar nature should be viewed by all.

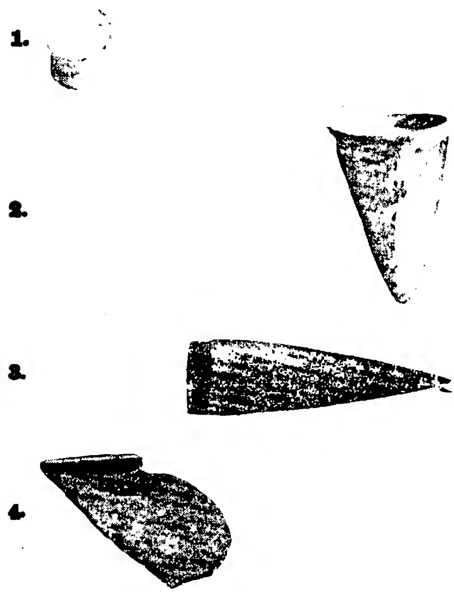


FIG. 227. Types of nets. 1. Dip; 2. Insect; 3. Tow; 4. Insect. Courtesy Gen. Biol. Supply Co.

Field equipment. The student should be equipped with a collecting net; at least one killing bottle (although two or more are desirable); a pair of fine forceps; a magnifier, preferably a Coddington lens, although any ordinary small magnifying glass will do; a carrying case such as a gas mask bag, school book bag, or one such as is illustrated in Fig. 228. The carrying case can be easily made

by the student. The student should also have small pasteboard boxes such as pill boxes; empty four-inch vials; homeopathic vials; vials partly filled with 80% alcohol; a field notebook of small size and a pencil; a pen knife is always useful. A pair of field glasses for bird observations is also desirable. Some general equipment, supplied by the teacher, can be distributed among the class. This equipment should include the material for general use. A few cloth bags, such as sugar sacks, are ideal for carrying snakes, frogs, and toads. In case the trip includes some ponds or streams, a dip net, bottom scraper, and a small bucket with a perforated lid should be taken. A small axe and a light-weight pick with a short handle, or better still a geologist's hammer, are useful in tearing apart dead logs and stumps. The hammer or pick can also be used for pulling out loose shale or for digging out larvae or other animals which live in burrows.

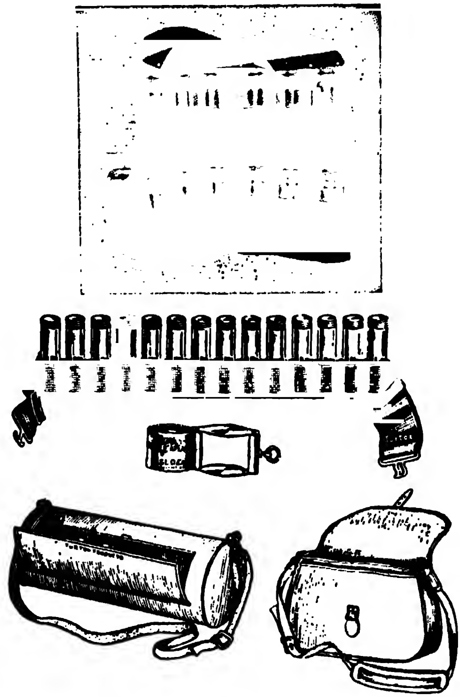


FIG. 228. Ideal field equipment. Courtesy Gen. Biol. Supply Co.

A camera for taking photographs of interesting objects is always desirable.

In regions where poisonous snakes are likely to be encountered, a snake bite outfit should be in the possession of the leader.

Field directions. On general trips the student of nature should look under stones and under objects on the ground for living things. The stems, leaves, flowers, and fruits of plants should be examined carefully; and ripened pods should be torn apart, for there are often minute creatures that lurk within them. The grasses and low plants should be swept with the collecting net. This is effected by

swinging the net back and forth among the plants close to the ground. Holes and crevices should be investigated since there are many animals which live in excavations and others which take shelter in any concealed opening when the collector approaches. The trunks and lower branches of trees should be carefully examined, and all of the creatures and plants should be observed or collected. Dead recumbent logs and tree stumps should be dug apart, and all kinds of creatures found in them should be taken.

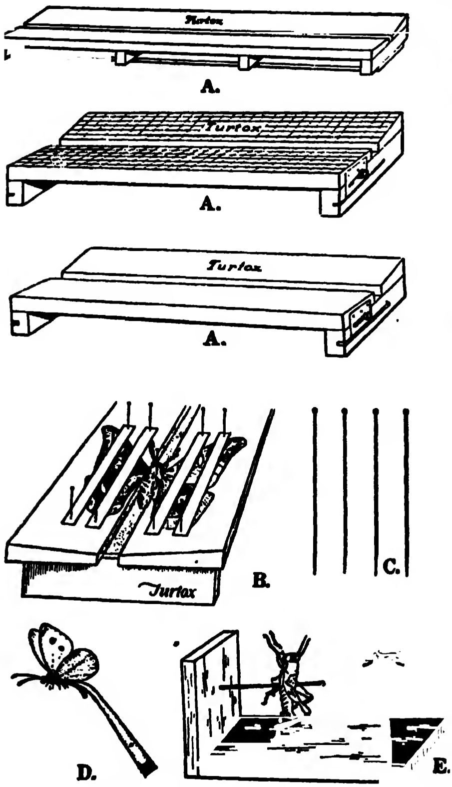


FIG. 229. Laboratory equipment. A. Spreading boards; B. Proper method for spreading winged insects; C. Insect pins; D. Spreading wings of a butterfly; E. Block for examining insects. A., B. courtesy Gen. Biol. Supply Co.; D., E. courtesy Ward's Nat. Sci. Estab.

It is evident that, collecting in this manner, the student will not get very far on a single trip, but thoroughness is essential in studying the life of a region.

On the ground and under objects you will see many kinds of insects, including ground beetles, tiger beetles, ants, crickets, grasshoppers of several kinds, digger wasps and other predatory hymenoptera, collembola, thysanurans, flies, tumble beetles, and numerous others. You will also find slugs, millipedes, spiders, centipedes, sowbugs, earthworms, snakes, lizards, salamanders, and scores of others. The nature of the habitat will determine just what kinds of organisms will be found in a given place. Some things will be found on dry ground, others on wet ground; while others are on the forest floor or in the open. On the ground stratum the burrows of many animals will be noted. These include holes made

by digger wasps; the holes in which the larvae of tiger and other beetles live; the openings of crayfish wells surrounded by chimneys of mud; tunnels of moles and meadow mice; groundhog burrows with their piles of barren earth at their entrances; the concealed openings of chipmunk burrows; spider nests and the nests of bumble bees and wasps. The nests of ground sparrows, ovenbirds, quail, grouse, pheasants, and other birds should be described and their contents noted; but they should never be disturbed. The barren trails on the ground are the runways of meadow mice and other animals, most of which can be identified by the nature of the trails themselves. The set-ups of rabbits in clumps of grass or in brush heaps will be recognized by the hollow places in the plants and by the fecal deposits. In the breeding season the rabbit excavations in which the young are deposited are pretty well concealed. In forest areas where deer abound, the sleeping places are revealed by the trampled plants.

FIG. 230. Method of mounting insects. After Kellogg, *American Insects*, courtesy Henry Holt and Co.

In the dead log there will be found bark lice; harvestmen; spiders; centipedes; snails; slugs; engraver beetles; many kinds of wood-boring beetles including click beetles, longhorns, clerids, cucujids, etc.; bugs, ants, roaches; larvae of beetles, horntails, and others. In hollow logs there are often toads, snakes, salamanders, deer mice and other mammals including skunks.

On the bark of trees there are harvestmen, plant lice, spiders, aphis lions, bugs, caterpillars, beetles, wasps, ants, slugs, snails, eggs of many kinds of insects, tree frogs, bark moths, lady bugs, mosses, lichens, and other plants. Many of these forms will be found in the crevices of the bark.

On the lower plants there are beetles of many kinds, butterflies, moths, caterpillars, plant lice, white flies, ants, lady bugs, spiders, flies, leaf hoppers, lace wings, grasshoppers, katydids, bees, wasps, thrips, stilt bugs, stink bugs, assassin bugs, and numerous other animals and galls. Some of these will be found on the stems, others on the upper and undersides of leaves, while still others such as bees, butterflies, many bugs and beetles, flies, and brightly colored spiders will be found on or in the flower. Flower heads and tubular flowers should always be examined because there are many diminu-

tive creatures that remain hidden deep in the throat of the corolla or among the minute flowers of a compact head. Many of the insects found on plants are more or less specific for those plants, and the plant identity should always be noted. Black blister beetles (*Epicauta*) are always associated with goldenrods; tiny snout beetles are found only among the compacted buds and flowers of the giant mullein; the rosy maple moth is usually found in the flowers of the evening primrose; the black-spotted, red milkweed beetles and the monarch caterpillar are found only on milkweed, as a rule; the golden greenish jewel beetle (*Chrysochus*) is found on *Euphorbia* and milkweed; and so on. It is important to record these specific plant selectivities for collected specimens.

The above suggestions are made to encourage the careful examination of the various situations in the field. The habitat classification listed elsewhere will indicate some of the things that are to be found in other situations.

In addition to collecting the smaller forms, all of the birds, snakes, mammals, and other creatures which are not collected should be recorded in the field book. If their identifications are not possible in the field, the animals should be carefully observed, and their descriptions should be included in the field notebook. When animal tracks are encountered, they should be sketched in the field notebook when the identification of their makers is not known. Carcasses of animals and excrement should be examined for carrion beetles, and visiting flies and other animals should be collected. In examining dead animals and fecal matter, the material should be turned over because many of the inhabitants of these materials are to be found under them as well as in them, especially histerids, staphylinids, silphids, scarabs, and other beetles.

When collecting in any situation, progress should be slow and as quiet as possible. A noisy approach causes many beetles to drop to the ground where they are very hard to find and see, and all other forms either scamper away or seek places of concealment. The collector should always endeavor to observe the various creatures at work and at play. This can be done only by careful procedures.

Each situation should be studied thoroughly, and complete data should be attached to every specimen.

Night trips should occasionally be planned, for there are specimens and activities which can be collected and seen during dark

hours that cannot be studied during the day. Strong flashlights can be used for collecting; and light screens, automobile lights, and moth traps will attract flying forms. Molasses and very ripe bananas smeared on the tree trunks will attract numerous insects.

Association studies. In classes where regular field trips are scheduled, the itinerary should include as many different situations as are readily accessible. In such classes the writer has found it advisable to submit a printed exercise which includes general directions for procedure in the field. The following exercise, taken from the author's *Systematic Guide to Field Biology* [1] will indicate the kind of exercise that has proved successful in his own classes. It is included here merely as a suggestion.

WOODLAND ANIMALS

(This exercise will require several trips.)

OBJECT: To become familiar with the animals indigenous to shady woodland areas.

DIRECTIONS: While many animals are to be found only in woodland situations, there are many types of woods. They may be old or young, sparse or dense, damp or dry, etc. Then, too, the vegetation itself will partly determine the life to be found in any woods. The forest may be evergreen or deciduous; and different trees such as oak, hickory, ash, or others may predominate in different areas. The procedure for study, however, is the same for all. Only the results will vary.

Woodland studies must be made slowly and patiently. Animals have numerous places in which to hide, and they are less easily found in shaded places than they are in open areas. At the first sign of danger, activity ceases, and animals warn each other of your presence. Birds stop singing and frequently sound alarms. Squirrels scamper out of sight. Insects remain quiet or seek places of safety. Thus it is necessary to approach and proceed quietly and slowly, keeping on the lookout for fleeing birds, insects, and mammals.

Examine the leaves and stems of the shrubs and the lower branches of the trees. Search carefully for forms on the ground and on the bark of trees. Capture flying insects. Record all bird, reptile, and mammalian observations.

Record carefully the exact situations in which animals are observed or taken. Note the height of nests, birds, mammals, and insects in the various forest strata. To fully understand the woodland animals this is necessary.

Careful studies will reveal chipmunks, squirrels, bats, snakes, land snails, box turtles, salamanders, lizards, frogs, and numerous birds, such as cedar wax wings, tanagers, pheasants, towhees, flycatchers, vireo

[1] *Systematic Guide to Field Biology*, by Samuel H. Williams, mimeographed edition.

woodpeckers, nuthatches, creepers, wrens, thrashers, warblers, blue-jays, crows, and others too numerous to list here.

Many insects characteristic of the woodland such as craneflies, walking-sticks, tree crickets, smoky-winged damsel flies, bark moths, thysbe moths, tachinid flies, scorpion flies, hornets, tree hoppers, etc., will be found by the careful searcher. Tiny masses of eggs can be found on the bark, and these often reveal minute, parasitic wasps laying their eggs in the eggs of the host insect. A magnifier makes the observation of these more interesting. Make your searches complete.

Open umbrellas and place them on the ground beneath a tree of moderate size. Shake the tree forcibly and gather fallen insects which tumble into the open umbrellas. The walking-stick is most easily gathered in this way.

Report

(1) List all animals observed and taken, giving their classification and common names. Be prepared to discuss life histories, habits, and the adaptive features of all specimens collected.
(2) Arrange them according to strata, e.g., ground, low shrubs, tree tops, etc.
(3) What animals in your list are truly woodland forms?
(4) What arboreal animals did you see?
(5) How did the various forms react to your presence?
(6) Use references on birds and mammals and add additional forms to your list.
(7) Make a diagram showing zonation of the woodland animals in your collection.

Collecting devices. There are many ways in which specimens can be trapped. Deep pits dug in the woods often prove of value in entrapping toads, frogs, snakes, small mammals, and other animals which roam about at night. The pits should be about three feet deep. Moth traps such as those sold by biological supply houses are very effective in capturing night-flying moths and other insects.

Carrion beetles can frequently be taken by the hundreds by placing a colander full of sandy earth in the ground and then placing excrement or the carcass of a dead animal on the sand. The carrion insects are attracted by the odors, and they burrow in the earth beneath the "bait." In a day or two the colander can be lifted and carried to a brook or creek where the sandy earth can be washed out through the holes in the colander leaving the insects in the vessel.

Another very effective trap for carrion insects can be made as follows: Place a fish head in a quart mason jar, securely tying some

cheesecloth or muslin over the opening of the jar. Make a small slit in the cloth covering. Take the jar to a woods or field near the woods and place it in an excavation with the top just flush with the surface of the ground. Pack dirt around the jar and loosely cover the top with dead leaves. Hang a strip of white cloth in a conspicuous position on an overhanging plant, so that the location of the trap may easily be found again. Several of these traps should be made. The traps should be placed in the late afternoon and allowed to remain over night. The next day visit the traps and examine them for animal forms. If no animals are present, it is probably because the material is not putrid enough to be odorous, and the traps should be left undisturbed to be visited later.

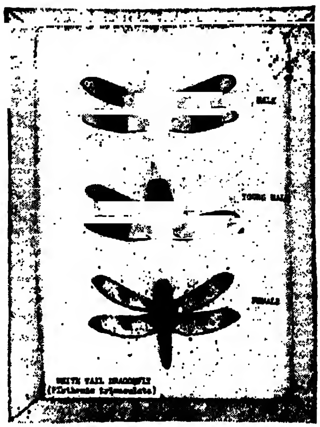


FIG. 231. A home-made insect mount made from an empty film box and a used photographic plate.

One trap should be left planted long enough for the animals to have started on their development. Later visits will yield larvae and pupae, and the life histories can be observed.

The animals in the jars may be taken with forceps and placed in a mixture of formaldehyde and alcohol to deodorize them and then either be mounted or preserved in 80% alcohol.

You will secure maggots, adult flies, histeridae, silphidae, staphylinidae, scarabeidae, dermestidae, and other insect forms. Another observation on carrion beetles should be attempted.

Place a dead mouse on the ground in the evening and cover it with crossed sticks so that prowling animals cannot carry it away. Look for the carcass the next day. If it has not disappeared, wait a day or two; and it will, in all likelihood, vanish. When the carcass has disappeared, lift the earth where the carcass was placed with a trowel. Look for animals beneath the buried mouse. You should find orange-and-black burying or sexton beetles.

Small bugs and beetles often drop to the ground at the slightest disturbance. Stretch pieces of cheesecloth on the ground beneath low bushes and then leave the place undisturbed for several

hours. The insects will ascend the plants; and when the collector returns, they will drop to the cloth where they can readily be seen.

Lights attract insects; and if a white cloth is stretched vertically in front of a lantern, and another piece is placed on the ground at the base of the vertical piece of cloth, attracted insects which fly against the cloth and drop can easily be taken. The flying forms which hover about the light can be captured with the net.

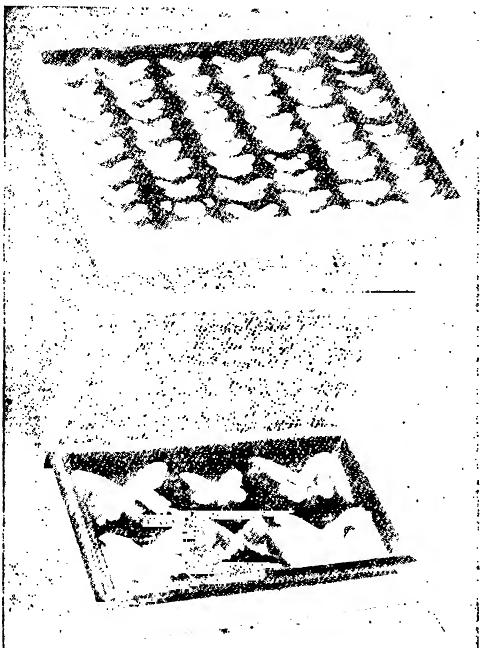


FIG. 232. Insect boxes. Courtesy Ward's Nat. Sci. Estab.

The type of insect net to use is a matter of preference. The experienced collector prefers a very light net of small diameter, but the beginner had better use a net with a diameter of 12 or 15 inches. Collecting nets of the types shown in Fig. 227 are very satisfactory, but others can be obtained. The net can be a home-made affair, and it will very satisfactorily serve for all purposes. The ring can be made of stiff wire, and the handle can be a piece of bamboo or a light broom stick. The ring can be attached to the handle by wrapping with wire and further securing it with staples. The bag can be made of cheesecloth, although bobbinet is much more desirable and endurable. The entomologist uses bags of several weights and meshes. The sweeping net must be of strong material.

In collecting water animals, home-made dip nets with strong rings, handles, and bags can be used, although the Needham bottom scraper (Fig. 235) and wire mesh dippers (Fig. 235) are much more satisfactory. Small wire strainers such as those used in

kitchens are very useful in collecting in small streams, pools, springs, or along the shores of ponds and streams.

A collecting screen made of a piece of fly screen about three feet long and attached to two sticks can be used effectively in collecting stream animals (Fig. 236).

There are numerous other devices for securing material, and these are pictured in the catalogs of the supply houses listed in Appendix B.

In collecting water animals, the muck lifted from the bottom should be spread out on the shore or upon a flat rock where it can be examined. Many of the captured animals cannot be seen immediately, but they will soon reveal themselves if the material is watched closely.

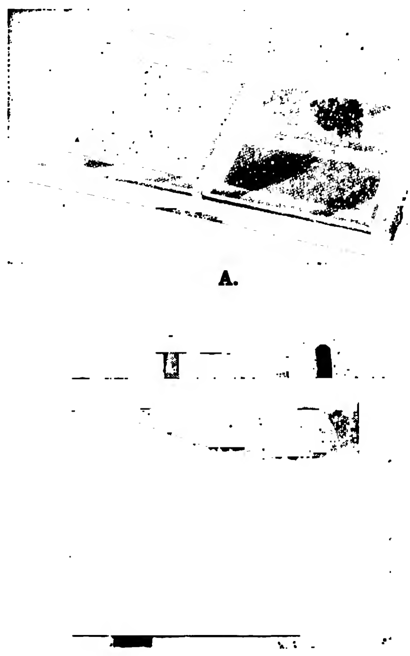


FIG. 233. Laboratory ant nests. A. Turtox nest; B. Austen nest in use. A. courtesy Gen. Biol. Supply Co.; B. original.

Collecting and preserving. Flying insects may be captured by the use of the net. This will seem a bit awkward at first, but practice and a knowledge of flight mannerisms will develop skill. Each form will exhibit a different kind of flight, and the student will soon observe flight differences between a Libellulid dragon fly and an Aeschnid, or between a fritillary butterfly and a Nymphalid, for instance. These differences will add considerably to the sport of catching flying insects. When an insect is caught in the net, the handle should be turned quickly to prevent its escape.

Butterflies should not be handled with the fingers. After capture in the net, they should be partly paralyzed by pinching their bodies at the bases of the wings from beneath. Then, when they are dumped into the killing jars, they will not mutilate their wings by flapping them against the sides of the jar.

All Lepidoptera (moths and butterflies) should be killed in separate jars. Do not place other insects, especially beetles and dragon flies, in jars with moths or butterflies.

Adult insects, such as beetles, bugs, flies, bees, wasps, crane flies, damsel flies, grasshoppers, crickets, mosquitoes, etc., should be killed in jars with potassium cyanide (KCN), carbon tetrachloride (CCl_4), or carbon disulfide (CS_2). The latter two chemicals are particularly desirable for small insects since they do not stiffen the joints.

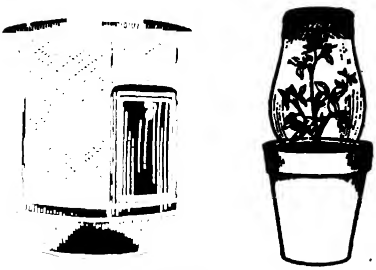


FIG. 234. Breeding cages for insects. Courtesy Gen. Biol. Supply Co.

After killing, the dead insects should be transferred from the jars to pill boxes or other suitable carrying receptacles and properly marked. Butterflies, dragon flies, and other large-winged forms should be placed in paper envelopes. DO NOT PUT TOO MANY INSECTS IN A JAR.

Soft-bodied animals such as worms, insect larvae, slugs, snails, lice, scale insects, spiders, ants, etc., should be placed in vials containing 80% alcohol or 15% formaldehyde. To preserve the natural colors of caterpillars and other forms, the vials containing alcohol should be placed in hot water as soon as possible after collection. It is frequently desirable to add a little glycerine to the alcohol.

Data. It is absolutely essential that complete records of each specimen be included in the field notes. As specimens are collected they should be numbered, and all data pertaining to them should be recorded under corresponding numbers in the field notebook. These data should include place or locality; situation (water, open field, woods, plants, on stem, leaf, kind of plant, etc.); activities (running, flying, digging, eating); climatic conditions (cloudy, bright, warm, cool); in shade or sunshine; nature of soil (sandy, humus, clay, wet, dry); exposure; altitude; hour and date of collection. Such data will be of value in studies of habitat selection, periods of activity, and distribution.

As soon as possible after collection, the locality, date, collector's name, and reference number should be attached to each specimen. For specimens preserved in liquids, a label written in India ink

and allowed to dry, and of a size adapted to the vial, should be inserted in the vial. Labels of pinned specimens should be printed in India ink. They should be very small and of uniform size. The lettering must necessarily be small.

Mounting. The large and medium-sized insects should be mounted on regular insect pins at a uniform height, which is such that there is room at the top for handling the pinned specimen with safety. Pinning blocks can be purchased from supply houses. Different insects require different mounting, and the following directions for the insertion of the pin should be followed. A pin of suitable thickness should be selected. A carborundum needle sharpener is useful for removing rust or straightening bent points.

FIG. 235. Types of water dippers. Courtesy Gen. Biol. Supply Co.

Flies should be pinned through the thorax, a little to the right of the median line.

Bees, wasps, crickets, grasshoppers, and bugs can be pinned through the thorax.

Beetles should always be pinned through the right wing cover. This makes it possible to see the entire left side when the pinned specimen is held between the fingers.

Butterflies and moths should be held between forceps at the bases of the wings. A little pressure on the forceps spreads the wings, and the pin can be inserted in the thorax without danger of rubbing off the scales. In mounting butterflies and moths, extreme care must be taken against rubbing off the wing scales. After the pin is inserted, place the specimen in the groove of a spreading board (Fig. 230).

Cut several strips of paper, making them longer than the depth of the front and hind wings. Move the front wings forward with a pin and place a strip of paper over it. The pin should be inserted just behind the anterior vein to prevent tearing. Then, in the same manner, move the hind wing forward under the strip of paper. The strip should be pinned securely to prevent the wings from slipping.

Mount the wings at the same angle on both sides and put the board in a dry place for several days or until the specimen is dry.

Carefully remove the paper strips and transfer the specimen to your insect box. This same procedure may be used for spreading the wings of dragon flies, grasshoppers, and other winged forms.

Small beetles should be stuck on the tips of small triangles of stiff paper with glue, balsam, or white shellac. The pin is placed through the broad end of the triangle.

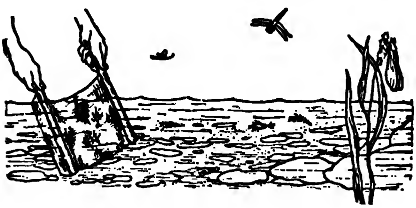


Fig. 236. The hand screen used in collecting water animals. Courtesy Ward's Nat. Sci. Estab.

Small wasps, flies, etc., may be mounted on a short section of a very fine pin or wire, and this inserted through a piece of pith attached to a pin heavy enough to be placed in the insect box.

Most small animals such as spiders, crustaceans, fleas, plant lice, collembola, thrips, lice, etc., are more easily studied when mounted on glass microscope slides.

The animal should be cleared in a hot 5% solution of potassium hydroxide and thoroughly washed with water. Transfer to 35% alcohol for twenty minutes and then to 50%, 70%, and 95% alcohol for the same length of time to dehydrate them. Place in cedar oil until the specimen is clear. Transfer to xylol for fifteen minutes and then place the specimen on a drop of balsam on the slide. Arrange the appendages with a fine pin and lay a cover glass over the embedded animal. This makes a permanent mount.

Snakes and lizards are best carried in a cotton bag. There are numerous methods of preserving large specimens such as toads, snakes, fishes, etc. A very simple one is to kill the animal in full strength formaldehyde and inject a 15% solution of the same.

The skeletons may be cleared by boiling in water until the flesh is removed and then boiling in hydrogen peroxide. It is easier to enlist the aid of ants and dermestid beetles, however.

Permanent collections. The specimens preserved in liquids should be placed in fresh solution in final storage bottles or jars, and properly labeled.

Mounted insects may be kept in cigar boxes or pasteboard boxes, but the most desirable containers are wooden boxes (Schmitt

boxes) with cork bottoms. Tight-fitting covers are necessary to keep out destructive pests, such as the larvae of dermestid beetles; and a spoonful of carbon disulfide should be placed in the box from time to time. Carbon disulfide is poisonous and highly inflammable. It is also well to place naphthalene in insect boxes. Naphthalene cones may be purchased, or very desirable preparations may be made by inserting heated pins in moth balls.

Suitable boxes can be made by placing layers of corrugated paper in the bottoms of pasteboard boxes having tight covers or in cigar boxes. A layer of white glazed paper should be glued over the bottom layer. Some insect boxes are shown in Fig. 232.

Riker mounts with cotton backgrounds and glass covers are splendid for exhibits to be handled in classes, but naphthalene crystals should be placed beneath the cotton layer and the whole tightly sealed. Small cardboard boxes make desirable home-made exhibition mounts (Fig. 231).

The Aquarium

A balanced aquarium is one in which there is a chemical balance between the animal and plant life present. The plants utilize the carbon dioxide given off by the animals, and they liberate free oxygen which sustains the vital processes in animals.

The aquarium is an essential part of the equipment of a student of nature. Any kind of a container can be used, and all of the material, both plants and animals, can generally be procured without cost in almost any section. Native plants and animals are much more desirable than exotic ones, although it is interesting to have some warm water tanks in which tropical conditions can be simulated.

The aquarium as an object for study is valuable in that it enables the student to make certain observations that cannot always be made in the field. In the home or laboratory it makes possible such observations as:

(1) The factors involved in the maintenance of a balance of chemical conditions between plants and animals;

(2) The factors involved in the sustenance of water life, including breathing, swimming, and physiological conditions and processes;

(3) The interrelationships which establish an association of water animals and effect distribution within a pond;

(4) The development of various water animals.

Directions. (a) Prepare several small aquaria by placing a layer of washed sand in the bottom of tumblers or pint jars. Partially fill each container with water and plant a spray of *Elodea, Cabomba, Myriaphyllum, Anacharis, Coratophyllum,* or *Sagittaria* in the sand and allow it to stand for a day. Then tiny fish, water snails, blood worms, mosquito larvae, or other small forms may be added. Do not place too many animals in one of these small aquaria.

Single forms may be raised through their entire life histories; and single specimens of larger beetles, water bugs, water scorpions, etc., may be kept in these for observation for a day or two.

(b) The class may construct several larger, rectangular aquaria for the purpose of observing "balance" and interrelationships.

A layer of clean, washed sand should be placed in the bottom of the tanks. The sand should be sloping toward one end for the purpose of making it easy to clean the aquarium from time to time. Waste matters will gravitate toward the lower end where they can be siphoned off. A layer of fine washed gravel should be placed on top of the sand. Add water until the tank is about half full. In adding water, it is best to place a piece of cardboard on the layer of sand and gravel and then pour the water on the card. Otherwise the even contour of the bottom material will be destroyed.

Then insert sprays of water plants such as *Vallesneria* and *Ludwigia* in addition to any of those already mentioned. It is best to group the plants at the ends of the tank. This leaves a clear space in the middle for observation. Then fill the tank. Floating plants such as duckweed or water hyacinths may be placed on the surface.

To balance the aquarium it is best to allow the water to stand for a day or two. Then add goldfish, minnows, sunfish, or catfish, the number being dependent on the size of the tank. A few water snails should be added, because most of these feed on the algae that ordinarily grow on the sides of the tank and frequently obscure vision from the sides.

If the fish hover at the surface, it is an indication that there are too many animals for the amount of plant material, and it is best to add some fresh water and either remove some of the fish or add more plants.

When the fish swim about freely and appear at ease, the aquarium is balanced; and if kept under the proper conditions, it will not be necessary to change the water.

Several things must be borne in mind in the preparation of a perfectly balanced aquarium. The tank should not be allowed to remain in direct sunlight for any length of time. Too much light promulgates the rapid growth of algae. If algae grow too rapidly on the glass, add more snails. Snails will lay their eggs in jelly masses on the sides of the aquarium. These may be examined through a magnifier each day and the entire development observed. Changes in temperature do not affect native animals in the aquarium, but the water *can* get too warm, and freezing will break the glass walls of the tank.

A glass cover, raised slightly at the corners to allow ventilation, will reduce the rate of evaporation and keep out dust.

To clean the aquarium, a piece of rubber tubing may be used to siphon out the waste which gravitates to one end in the sloping bottom. A convenient drip-tube is sold by supply houses.

These directions apply to permanent aquaria, and many kinds of fish may be kept in this way if temperature conditions are kept favorable. For tropical fish it is best to hang an electric light over the tank.

Most stream fish and goldfish can be fed on granular fish food. A mouthful of food per day will keep a fish active and healthy. When daphnia can be cultured or obtained, it is advisable to use them at least occasionally for food. Some ground shrimp can be added to the diet. Meal worms, earthworms, or hamburger can be fed to some fishes and to salamanders.

Two "don'ts" should be emphasized. *Don't overfeed;* many people lose their goldfish because of overfeeding. *Don't transfer fishes from warm water to cold water.*

If it becomes necessary to change the water, make sure that the temperature of the fresh water is about the same as that which is removed. Fish can withstand gradual changes of temperature, but sudden changes usually have fatal results.

(c) In one of the larger tanks place some of all the kinds of water animals you have collected.

Keep a record of the number of each kind added and observe results. Some will feed on others and eventually exterminate them. Stream forms will die from lack of oxygen. Others will

not find suitable bottom conditions, and others may be affected by the higher temperatures of laboratory aquaria.

Observe the positions assumed by the various animals. Note stratification, distribution, locomotion, burrowing habits, etc., of the inhabitants in the tank.

Obstruct the light from one end or an end and a side of the tank and observe the movements of the animals. If the tank is in a dark place, hold a light at one end and note the responses of the animals.

Cover the top, ends, and sides with cardboard, leaving two equal openings on the sides. Then lift the card from the top and determine the distribution within the tank. These procedures will indicate the phototropic responses of water animals.

After from one to two and three days check the numbers and kinds of animals remaining in the aquarium. Check again after a week and at regular intervals thereafter until the association of animals is fixed.

Measure the hydrogen ion concentration and oxygen content of the water twice each day if possible. A La Motte pH indicator [1] is quite satisfactory for the hydrogen ion determination.

Suspend a thermometer in a corner of the tank and record the temperature twice each day. Some of the interesting aquarium studies include the following:

(1) Describe the life histories of forms raised.

(2) Describe the distribution of forms in the mixed aquaria (bottom, attached to plants, surface, burrowing, attached to sides, free swimming, etc.).

(3) Describe the locomotion of animals observed.

(4) Which animals are predatory? Do these prey upon a certain kind of victim?

(5) Which ones die apparently from lack of suitable conditions? Compare the conditions in the aquarium with the normal habitats of these forms. Suggest the causes of death.

(6) Which animals go to the surface for air? How do they get it?

(7) Which animals are truly aquatic?

(8) What are the various adaptations for breathing under water, swimming, capturing food?

[1] Made by La Motte Chemical Co., Baltimore. Block indicator for the colorimetric determination of pH.

(9) What animals are crawlers?

(10) Which ones are protectively colored? How?

(11) Which ones have "stream-line" forms?

(12) Describe the exchange of materials between plants and animals in aquatic situations.

(13) After three days what animals have disappeared?

(14) What animals constitute the final fixed association?

(15) List the causes of disappearance of missing forms.

(16) Summarize your observations on the behavior of the various animals.

(17) Is there any connection between the pH and O_2 content and the disappearance of animals?

(18) Were temperature changes sufficient to be a factor in mortality?

(19) What were the phototropic responses of the animals to light? Which were positive and which were negative in their responses?

Aquarium plants. The following plants can be utilized in stocking aquaria. The selection of plants should be made according to the size of the tank. (1) Tape grass or eel grass (*Vallesneria*). (2) *Elodea*. (3) *Anacharis*. (4) Fanwort (*Cabomba*). (5) Water purslane (*Ludwigia*). (6) Floating *riccia*. (7) Duckweed (*Spirodela polyrrhiza*), a small floating plant. (8) Duckweed (*Lemna*). (9) Bladderwort (*Utricularia*). (10) Water fern (*Salvinia*). (11) Water moss (*Hypnum cryophyllum*). (12) Water hyacinth (*Eichhornia azurea*), a floating plant. (13) Fr· · bits (*Hydrophers morphus*). (14) Triannia. (15) *Azola carolinana*. (16) Water aloe. (17) Dwarf water lily (*Nymphaea odorata*).

Many of these can be collected by the students or they can be obtained from florists or from the biological supply houses listed in Appendix B.

Vivaria and terraria. Many kinds of small animals can be kept indoors for observation. Periods of gestation, fecundity, and numerous other biological principles can be studied in this way.

Breeding cages for terrestrial insects can be made from small wooden boxes, and fly screen or glass sides can be used. Earth placed in the bottom will sustain growing plants on which many insects feed.

Ants can be kept for several years in artificial nests such as those shown in Fig. 233. Crickets, mantises, walking-sticks,

grasshoppers, and caterpillars can also be kept for observation in the chimney cage shown in Fig. 234.

An ordinary aquarium tank with a glass extension top is an excellent vivarium for raising ferns and log plants (Fig. 238).

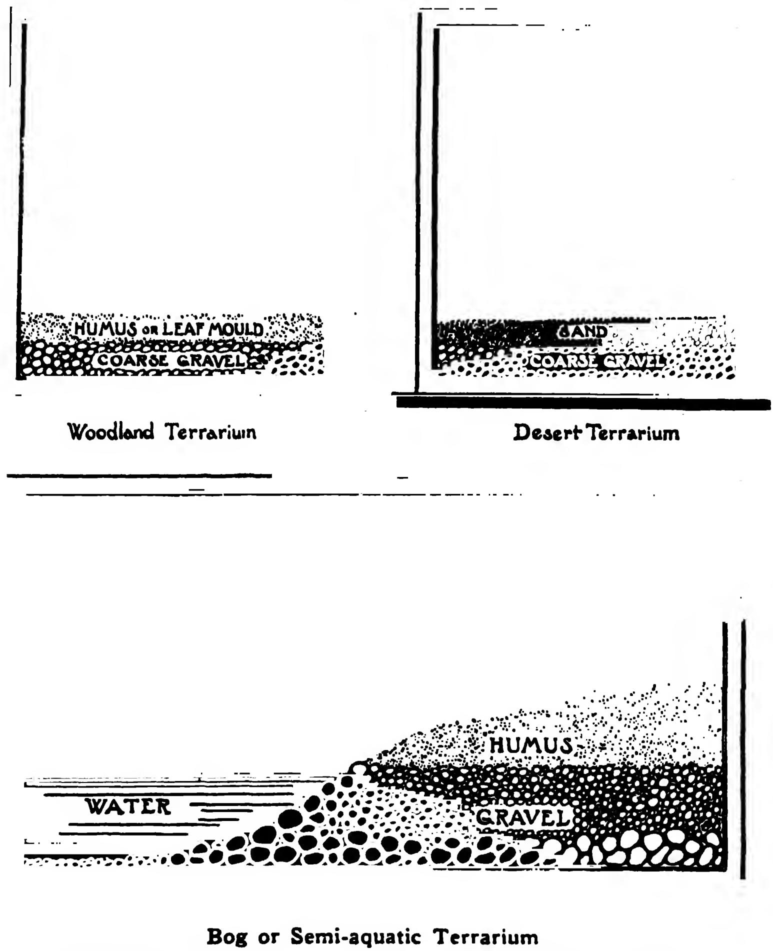


Fig. 237. Types of vivaria. Courtesy Gen. Biol. Supply Co.

The life histories of water insects can be observed by putting a screen extension above the aquarium in order to provide space for the aerial stages. The semi-aquatic terrarium illustrated in Fig. 237 is ideal for frogs, salamanders, snakes, crayfishes, and other animals.

The aquarium tank can be used for duplicating almost any local condition (Fig. 237).

Many types of breeding cages, terraria, vivaria, and aquaria are sold by biological supply houses. Field mice, snakes, and other animals can be studied alive by caring for them in the laboratory and such studies are always worth while.

Plant Study

Studying plants in the field. The writer is unalterably opposed to the practice of requiring a collection of mounted plants from each member of the class. In some sections where this practice was in vogue for many years, there is a paucity of spring flowers. In large classes where each student made a collection of 50 plants, the countryside became denuded of its early flora by the collectors, few of whom ever made any subsequent use of their specimens.

Fig. 238. A vivarium for plants. Courtesy Gen. Biol. Supply Co.

The modern idea of conservation has superseded the practice of exploitation, and a good slogan is to "love 'em and leave 'em." It is not necessary nor particularly beneficial to collect the plants in order to study them. A herbarium of native plants is an excellent thing to have in a school, provided the plants are mounted in protective envelopes with transparent covers so that they may be examined without injury. The building of the herbarium collection makes an excellent class problem.

Identities, longevity, methods of growth and propagation, habitats, conditions under which plants grow, the aspects of colors, methods of pollination, seeds, seasons, and the usual structural features of plants can all be studied without destroying the plants. Where natural parks or undisturbed land areas are available nearby, it is an excellent thing to transplant as many species as possible to these more accessible places. Care must be taken to select a situation as nearly similar to the original habitat as possible. This requires a pretty thorough knowledge of the plants,

and it is valuable information to acquire through class studies. It also makes an excellent hobby for the one who studies nature for recreation.

Identifications, as such, are of secondary importance. Most classes learn only the spring flowers before school closes. Then

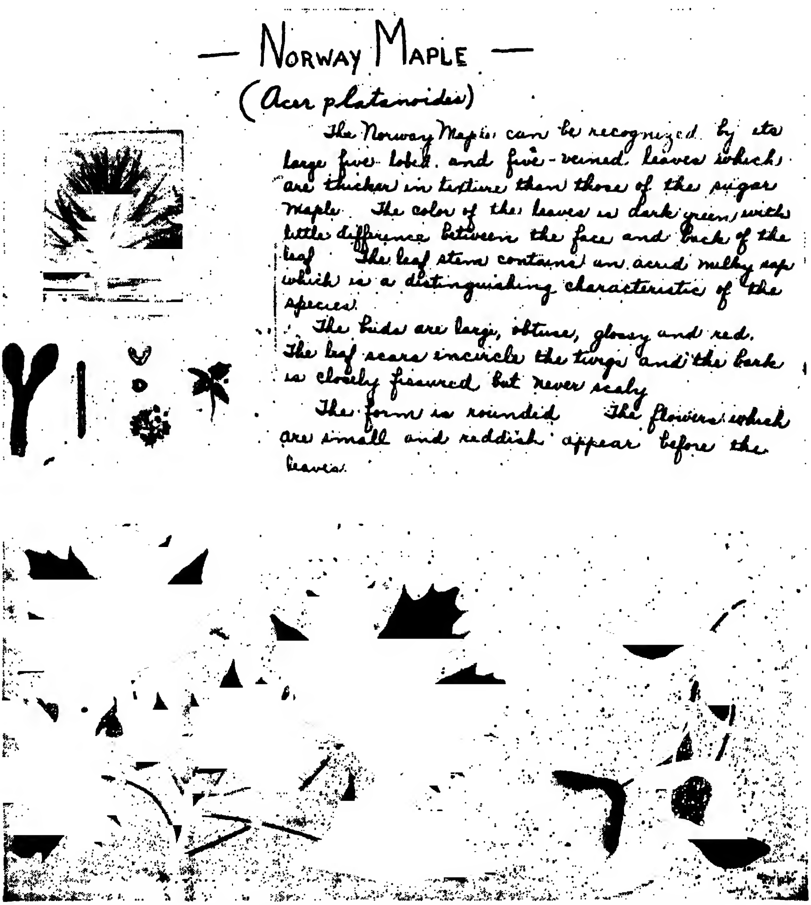


FIG. 239. A tree mounting. (A student-teacher's device.)

come the summer and early fall flowers which they seldom learn to know.

The information implied in the discussions of the phases of plant studies, such as protection, pollination, etc., should be an objective in studying plants in their natural haunts; and cer-

tainly seasonal succession should be ascertained. But get this information without destroying either the flowering plants which everyone enjoys or the plants which provide food for birds. Dogwood, rhododendron, laurel, bittersweet, locust, wild crabapple blossoms, and the other beautiful flowering plants which transform the woods, fields, and roadsides into fairylands of beauty should never be molested. To these a multitude of city dwellers whose vision is circumscribed by skylines of towering buildings, factories, and smoke stacks throughout the weeks look for recreation, relaxation, and inspiration.

Make and keep the countryside as beautiful as possible; for nature in its glory provides an aesthetic atmosphere which is conducive to the development of those virtues such as reverence, humility, and respect, which are essential in the quest for happiness and in the cultivation of proper conduct.

YEAR	FIRST SEEN	BY WHOM	WHERE	NEXT SEEN
1929	APRIL 29	J. lloyd	Campus	MAY 1
1930	MAY 2	G BURR	Faller.	MAY 2
1931				
1932				
1933				

FIG. 240. A type of individual bird calend·. From Allen, *Book of Bird Life*, co·.tesy D. Van Nostrand Co., Inc.

The Nature Study seminar. It is obvious that in a bibliography as extensive as that included in the text, specific text references are out of the question. It is also evident that it would not be possible to cover the whole field of literature in a single course. However, much additional information can be acquired by having the students report on various books and papers included in the bibliography, in organized seminars.

The seminar can be a science club or it can be included as a part of the course. Students can present abstracts of works pertinent to the phase of the subject under discussion. The writer has found these seminars to be helpful and inspiring to the class. They contribute much to sustained interest.

APPENDICES

APPENDIX A

INTERESTING FACTS ABOUT NATURE IN QUESTIONS AND ANSWERS

General Information Questions

1. What trees bloom before they leaf?
2. Name five nut-bearing trees.
3. What are the differences between pines and other evergreens?
4. To what family of plants does the apple belong?
5. What does an "apple worm" grow up to be?
6. What are "ant cows"?
7. What mosquito carries malaria?
8. Name some relatives of the oyster.
9. Is the chickadee a harmful or a helpful bird?
10. What are the objections to the English sparrow?
11. What is a balanced aquarium?
12. To what group of insects does the "potato bug" belong?
13. Name five poisonous plants.
14. Do snakes lay eggs?
15. What is the difference between a butterfly and a moth?
16. What group of insects are "suckers"?
17. What means of defense has a toad?
18. Does an earthworm have feet?
19. What does an "army worm" grow up to be?
20. Do dragon flies deserve the name "snake-feeders"?
21. What is a "grubworm"?
22. What do snakes eat?
23. What insects have a highly specialized social order?
24. What common plants depend upon the wind for distributing their seeds?
25. Name ten winter bird residents.
26. What is meant by hybridization?
27. How do insects carry pollen?
28. What is a beetle?
29. Name five edible wild plants.
30. What are the differences between a reptile and an amphibian?
31. Why do flowers have bright colors?
32. What makes leaves change color in the fall?

33. When are trees tapped for syrup and why?
34. Name several shade trees and give their advantages.
35. Why are some trees that are commonly used for decorative and shade purposes objectionable?
36. What are the following woods most generally used for: ash, walnut, maple, cherry, oak, white pine?
37. How may the breeding of mosquitoes in ditches and pools be prevented?
38. What are fossils? Where are they found? Of what value are they?
39. Why are aquatic snails desirable in an aquarium?
40. Name two harmful birds and tell in what ways they are destructive.
41. How may the food of certain birds be determined?
42. What are the qualifications of a martin house?
43. Name five rodents.
44. How may forest fires be prevented?
45. Why do green plants need sunlight?
46. Name ten spring flowers.
47. What are seventeen-year locusts?
48. Name five plants that depend upon animals for distributing their seeds.
49. What are "ballooning spiders"?
50. How many points has a snowflake?
51. Name ten beneficial birds.
52. Name five plants that grow under water.
53. What bird calls "teacher" in its song?
54. What Order of insects is called the "singing Order"?
55. Do ants ever have wings?
56. What kind of an insect is the "lightning bug"?
57. What is the second stage in the development of the house fly?
58. How may the English sparrow be distinguished from other sparrows?
59. Are all sparrows harmful?
60. Why is the blue-jay not usually protected by law?
61. What Order of insects has two wings?
62. What are the differences between a dragon fly and a damsel fly?
63. What do lady beetles usually eat?
64. Name three fungus plant diseases.
65. What are some enemies of trees?
66. In what way is the "daddy-long-legs" beneficial?
67. Are all insects "bugs"?
68. What are the differences between a spider and an insect?
69. Name some animals that may be found at the bottoms of ponds.
70. Give the distinguishing characteristics of the silver maple and the American elm.

71. Name some ways in which plants protect themselves.
72. Name our native snakes that are poisonous.
73. What bird has the distinction of relishing the potato beetle?
74. What does a "wireworm" grow up to be?
75. What mammals live in trees?
76. How many kinds of locomotion are there among animals?
77. Describe a frog's egg and explain its adaptive features.
78. Describe the appendages of a crayfish and explain their functions and adaptations.
79. How may the wing, feet, bill, and tail of a bird suggest its habits?
80. What secondary sexual characters are found among birds and mammals?
81. Describe the adaptations of a mole to subterranean existence.
82. Classify our native mammals under the following: aerial, terrestrial, aquatic, arboreal, and subterranean.
83. What are the means of defense in mammals?
84. How do animals respond to seasonal changes?
85. How does an eagle soar?
86. How do animals of the same kind find each other?
87. How does a grasshopper see?
88. How does a fly walk upside-down?
89. What are the habits of a beaver?
90. How does a frog see under water?
91. Where do insects lay their eggs?
92. How does a bee manufacture wax?
93. Where do "groundhogs" go in winter?
94. How do spiders make their webs?
95. What causes a rainbow?
96. What is a "fairy ring"?
97. Of what value are vultures?
98. What is the most brilliantly colored mammal in the world?
99. How do rabbits warn others of approaching danger?
100. Name the ways in which stream-inhabiting animals protect themselves from the current.
101. What birds inhabit marshes?
102. Can bats see in the daytime?
103. Do bats carry bedbugs under their wings?
104. What is the largest bat in the New World?
105. What mammals really construct homes?
106. What are the differences between Old World and New World monkeys?
107. Is it possible to distinguish between male and female ruffed grouse in the field?

108. Can male bees sting?
109. Does the number of "rattles" on a rattlesnake indicate age?
110. Is age the principal factor in determining the number of tines on the antlers of deer?
111. Can dragon flies sting?
112. What factors determine the distribution of life in a pond?
113. Why do horse traders look at the teeth of a horse before they buy?
114. What is a mule?
115. What are ruminants?
116. What mammal is most highly specialized for living in trees?
117. Can all bears climb trees?
118. What is an animal's "environment"?
119. What common birds are thrushes?
120. How can a minnow be identified?
121. How does a cricket "sing"?
122. What are "night-crawlers"?
123. What water insects kill fish?
124. Describe the life history of the "hellgrammite."
125. What kind of insects are water striders?
126. Can any native snakes "spit" poison?
127. Do snakes "charm" people?
128. What bird impales its surplus food on thorns?
129. Where does the female waterbug usually lay her eggs?
130. What do dragon flies eat?
131. What interesting modification has the mole cricket?
132. Name some beneficial wasps.
133. Do little flies grow up to be large flies?
134. To what animals is the "sowbug" or "pillbug" related?
135. What bird lays its eggs in other birds' nests?
136. What common birds lose their brilliant plumage after mating?
137. Where do bats go in the winter?
138. In what ways do insects defend themselves?
139. What native animals hibernate?
140. What common birds catch insects on the wing?
141. Are these birds brightly colored? Why?
142. What insects are household pests?
143. Are moths and butterflies harmful?
144. Where are sticklebacks found?
145. In what ways are fungi beneficial?
146. How may the larva of an insect be distinguished from a worm?
147. Name some common worms.
148. How many legs has an insect?
149. How many eyes has a spider?

150. Do all spiders make webs?
151. What is a "measuring-worm"?
152. How can a flicker be distinguished from a meadowlark?
153. Of what use are antennae or "feelers"?
154. What common house plants grow from bulbs?
155. What animals furnish us with food?
156. What trees are noted for their attractive autumn foliage?
157. Name five flowering ornamental shrubs.
158. Do any salamanders have scales?
159. What is the largest salamander in the world?
160. Do all moths spin cocoons?
161. Are all moths nocturnal?
162. In what mammals do the teeth continue to grow during all or part of their lives?
163. How are the appendages of insects modified for swimming?
164. How do the immature stages of insects breathe under water?
165. Do adult insects breathe under water?
166. How can birds of prey be distinguished?
167. In flying do the wings of birds vibrate vertically?
168. How are the bodies of birds made buoyant for aerial travel?
169. Why does water run off a duck's back?
170. Where are the legs of diving birds situated with respect to position on the body?
171. How does this position compare with that on terrestrial birds?
172. How do trees prepare for winter?
173. What common mammal washes its food before eating it?
174. What animal produces the fur known as ermine?
175. What song-bird builds a hanging nest?
176. Is moss on a tree always a sure sign of North?
177. Does a beaver use its tail as a shovel?
178. What is Hudson seal fur?
179. What oriental mammal is noted as a snake killer?
180. What is caviar?
181. When a horse gets up from a reclining position, does it get up on its front legs or its hind legs? Why?
182. When a cow arises from a reclining position, does it get up on its front or hind legs? Can you explain this?
183. What are the young of ducks, geese, swans, and turkeys called?
184. What disease that is frequently fatal to humans is transmitted by rabbits?
185. What bird has a barbed tongue?
186. What is the smallest American game bird?
187. Does a calf or a foal (colt) have the longer legs at birth? Why?

188. What common animals are active only at night?
189. What native animals live on carrion?
190. Are all brilliantly colored birds permanently so?
191. What native mammal lines its nest with hair plucked from its own body?
192. What native mammals are blind at birth?
193. What native birds are almost extinct?
194. Of what value is countershading in animals?
195. Can insects discriminate among colors?
196. How can a millipede be distinguished from a centipede?
197. What common birds use their tails as props?
198. Which has the longer tail, a swift or a swallow?
199. What is an "electric light bug"?
200. What is the smallest North American mammal?

GUIDE TO THE ANSWERS OF THE GENERAL INFORMATION QUESTIONS

NOTE: It is obvious that to completely answer all of the questions in the preceding list would require more space than this book will allow. Most of the answers can be found in the text and these will be indicated. The answers listed here must necessarily be brief.

1. Some maples, juneberry, poplar, dogwood, basswood, etc. Others are listed elsewhere.
2. The linden, beech, oak, hazelnut, buckeye, are nut-bearing trees.
3. Pine leaves are long and occur in clusters of from 2 to 5. See chapter on Trees.
4. The apple belongs to the rose family.
5. An "apple worm" grows up to be a codling moth.
6. Ant cows are plant lice which exude "honey dew." See Insects.
7. The female Anopheles mosquito carries malaria.
8. Mollusks such as clams, scallops, and snails are related to the oyster.
9. The chickadee is a beneficial bird.
10. The English sparrow is indiscriminate and untidy in its nesting habits and it is pugnacious, driving other birds away.
11. A balanced aquarium is one in which the plant life is sufficient to supply oxygen for the animal life present. The water need not be changed.
12. The "potato bug" is a beetle.
13. Five poisonous plants are poison ivy, poison sumac, bitter nightshade, poison hemlock, snow-on-the-mountain (*Euphorbia*), and nettle.
14. Some snakes such as the blacksnake, milksnake, etc., lay eggs. See Reptiles.
15. The differences between a butterfly and moth are explained under Insects.
16. The bugs are sucking insects.

17. The toad has protective coloration and mucous glands which secrete a poisonous and offensive liquid.

18. An earthworm has bristles or setae which serve as feet.

19. An "army worm" is the larva of a moth.

20. Dragon flies have many names which are superstitious. They do not feed or "doctor" snakes.

21. A "grubworm" is the whitish larva of a May beetle.

22. Snakes devour mammals, birds, amphibians, and other reptiles. Some of them eat insects.

23. The ants, termites, and bees have highly specialized social orders.

24. Milkweed, wild lettuce, asters, goldenrod, dandelions, and many other seeds are adapted to wind dispersal.

25. Some winter bird residents are: chickadee, goldfinch, brown creeper, nuthatch, titmouse, cardinal grosbeak, and others according to geographical location.

26. Hybridization is the crossing of related species.

27. Pollen adheres to the hairy bodies of many flying insects, and in plants which produce pollinia the insects carry the pollen-bearing structures on their feet.

28. A beetle is an insect which usually has a hard or horny external skeleton and whose outer or front wings meet so as to form a straight line down the middle of the back or dorsal side.

29. A number of edible plants, or plants which have edible parts, are listed in the chapter on Plants.

30. The differences between a reptile and an amphibian are discussed in the text, but the scaly skin of the reptile in contrast with the smooth and often slimy skin of an amphibian is the chief visible character.

31. The bright-colored flowers usually depend upon roving agents for transferring and receiving pollen. Insects, which are the chief agents, are attracted to the bright colors.

32. Leaves change color in the fall because the green chlorophyll breaks up into its constituent pigments. See Plants.

33. Trees are tapped for syrup in the spring because the sap is rising and liquids rise in the outer portion of the stem.

34. The advantages of certain trees for shade purposes are discussed in the chapter on Trees.

35. Some trees, such as poplars, are objectionable for shade purposes on streets and in yards because of their aberrant root growths. The roots sometimes break sidewalks, water and gas lines, and sewers.

36. The uses of woods are discussed in the chapter on Trees.

37. Mosquitoes may be kept from breeding in ditches and pools by placing oil on the water. The film formed by the oil makes it impossible for larvae and pupae in the water to obtain air at the surface.

38. Fossils are the preserved remains of plants and animals that are frequently found in rock strata. They are of value in that ancient plants and animals can be studied from the standpoint of evolution.

39. Aquatic snails of certain kinds devour the algae that grow on the walls of the aquarium and thus keep the interior visible.

40. Harmful birds are discussed in the chapter on Birds.

41. The food of birds can be largely determined by the form and structure of the bill. See chapter on Birds.

42. A martin house should have many compartments and entrances, since these birds prefer to live in colonies.

43. Rodents are gnawers such as rats, mice, squirrels, beavers, and woodchucks.

44. Forest fires are mostly due to carelessness and may be prevented by exercising caution in throwing away lighted cigars, cigarettes, and matches and by making certain that camp and picnic fires are extinguished before leaving the woods.

45. Green plants need sunlight because the photosynthesis effected by the chlorophyll can take place only in the presence of light.

46. Some common spring flowers are: hepatica, spring beauty, jack-in-the-pulpit, dog-tooth violet, skunk cabbage, trailing arbutus, lady's slipper, anemone, crane's bill, squirrel corn, and others.

47. Seventeen-year locusts are cicadas. These are sucking insects related to plant lice and they are the largest of the Homoptera. It requires almost seventeen years for them to complete their metamorphosis.

48. Such plants as Spanish needles, beggars' ticks, hound's tongue, cockle bur, and sweet cicely depend upon animals for distributing their seeds. The seeds adhere to the coats of the animals.

49. Ballooning spiders are small spiders of several kinds which ascend to the upper parts of plants where the breezes blow, and then spin long buoyant threads which soar with the wind and carry the spiders with them.

50. A snowflake has six points.

51. Almost any ten birds that can be spontaneously recalled will be beneficial.

52. A list of submerged water plants is given in the text.

53. The ovenbird calls "teacher, teacher, teacher" in its song.

54. The Orthoptera, to which grasshoppers, crickets, and katydids belong, is called the "singing Order."

55. The reproductive members of an ant colony have wings during the nuptial flight only. The wings are removed after the wedding journey.

56. The "lightning bug" is a beetle.

57. The second stage in the development of the house fly is a maggot.

58. The chief distinction of the English sparrow is the white on the

"shoulders"; the male has black on the throat, breast, and abdomen. See technical description in Chapman's *Handbook*.

59. All sparrows are beneficial. Even the English sparrow has beneficial qualities.

60. The blue-jay is not protected because it is supposed to destroy the nests and eggs of other birds.

61. The Order Diptera, including the flies and mosquitoes, has but one pair of true wings.

62. The dragon flies and damsel flies are discussed in the text. Space prohibits the repetition of the differences between them here.

63. Lady beetles or "lady bugs" and their larvae mostly eat plant lice.

64. There are many fungus plant diseases such as the chestnut blight, corn smut, white pine blister disease, and wheat rust. The germs of tuberculosis, typhoid fever, pneumonia, ringworm, and other diseases of humans may be considered as fungus diseases.

65. Some enemies of trees are: fire, insects of many kinds, humans, fungus diseases, fungi, parasitic plants, etc.

66. The daddy-long-legs or harvestman devours destructive plant lice and other insects.

67. All bugs are insects, but not all insects are bugs.

68. A spider has eight legs, eight simple eyes, and two main body divisions; while an insect has six legs, two compound and usually three simple eyes, and three main body divisions.

69. Pond dwellers are listed in the chapter on Animals of ponds.

70. The distinguishing characters of the silver maple and the American elm are given in the chapter on Trees.

71. Plants protect themselves by poisons, noxious odors, spines, hairs, and other mechanical devices. See text.

72. The copperhead, rattlesnake, water moccasin, and coral snake, with all of the subspecies of these, are poisonous. See chapter on Reptiles.

73. The rose-breasted grosbeak is the only native songbird that seems to relish the destructive potato beetle.

74. A "wireworm" is the larva of a click or snapping beetle.

75. Squirrels, raccoons, opossums, and the fisher are tree dwellers. See the chapter on Mammals.

76. The kinds of locomotion among animals are: crawling, walking, jumping, flipping, swimming, gliding, and flying.

77. A frog egg is fully described and discussed in the text. See Water animals.

78. The appendages of the crayfish are fully described and discussed under Water life.

79. The adaptive features of the wing, feet, bill, and tail are discussed in the chapter on Birds.

80. Secondary sexual characters are those possessed by only one sex. These are numerous and include color, horns and antlers, wattles. Many of them are discussed in the chapters on Birds and Mammals.

81. The adaptive features of the mole are fully described in the chapter on Mammals.

82. The ecological classification of mammals is given in the chapter on Mammals.

83. Mammals defend themselves by: odors, horns, hoofs, jaws, quills, etc. See chapter on Mammals.

84. The responses of animals to seasonal changes, such as migration, hibernation, etc., are discussed in chapters dealing with Birds, Reptiles, Amphibians, and Mammals.

85. Soaring is effected by a special type of wing structure and by upward air currents. See chapter on Birds and also Clark's *Animals of Land and Sea.*

86. Animals find each other by calls, odors, structures, and vibrations.

87. The mosaic vision of insects is discussed under Insect eyes.

88. A fly is enabled to walk upside down by the presence of adhesive pads on the feet. See chapter on Insects.

89. The habits of the beaver are discussed in the chapter on Mammals and in numerous references suggested.

90. The presence of a transparent, nictitating membrane on the eye of the frog makes it possible to keep its eyes open under water.

91. Insects lay their eggs in and on plants, in water, in the bodies of living and dead animals of many species, on the external coats of animals; and in and on each other. See chapter on Insects.

92. The "bee sweat," or wax used by honey bees, exudes from between the wax plates on the abdominal segments. See Bees in text.

93. Groundhogs or woodchucks hibernate in burrows below the frost line in winter.

94. The web of a spider is made from a liquid which exudes from the spinnerets. The liquid solidifies upon contact with air. See chapter on Spiders.

95. A rainbow is caused by the refraction of light in spherical raindrops.

96. A fairy ring is a ring of fungi, usually found around the base of a tree which has been cut down. The circle widens as food is exhausted.

97. Vultures are great scavengers and remove the carcasses of dead animals.

98. The most brilliantly colored mammal in the world is the mandrill.

99. Rabbits always thump the ground with their hind feet to warn

others of approaching danger. The rapidly disappearing white tail may also suggest to others that they scoot to cover.

100. Stream-inhabiting animals that cannot swim against the current usually live under stones or in burrows on the bottom; or they may have means of attaching themselves by threads. A number of these are discussed under Stream animals.

101. Sandpipers, willets, yellow-legs, herons, bittern, killdeer, snipe, marsh wrens, marsh hawks, and many others.

102. Bats can see in the daytime.

103. Bats do not carry bedbugs under their wings.

104. The largest bat in the New World is a huge vampire, a carnivorous bat taken recently by Dr. Raymond Ditmars in Trinidad. It has a spread of nearly forty inches.

105. Few mammals make complicated houses in which to live. Our native muskrat and beaver and some squirrels and mice make rather complex nests. The orang utan and gorilla also make nests of woven branches. See Animal homes.

106. The Old World monkeys have cheek pouches and lack prehensile tails. The New World monkeys have no cheek pouches and many of them have prehensile tails.

107. It is not possible to distinguish between a male and female ruffed grouse on the basis of flight or coloration

108. Male bees cannot sting.

109. The number of "rattles" on the tail of a rattlesnake is not a means of determining age.

110. The number of tines or branches on the antlers of deer is not wholly dependent on age but rather upon nutrition.

111. Dragon flies are harmless insects and can be handled with impunity.

112. Depth, turbidity, plant life present, temperature, and other animals present are some of the factors which determine the distribution of life in a pond.

113. Horse dealers examine the teeth of prospective purchases because the teeth of horses grow until the middle life of the animal. Browsing keeps the teeth worn and the growth is to compensate for the wear. The length and condition of the teeth indicate the age and health of the animals.

114. A mule is a hybrid animal obtained by crossing a horse and an ass. Mules are usually sterile, although there are a few records of fertility.

115. Ruminants are cud-chewing mammals such as cattle, oxen, sheep, deer, and goats. These have a four-chambered stomach and food is chewed slightly and swallowed. It is stored in a paunch and may be regurgitated for further chewing.

116. The sloth is more highly specialized for arboreal existence than any other mammal.

117. Not all bears can climb trees. The black, brown, or cinnamon bear is the only native bear that can climb. See Mammals.

118. The environment of an animal consists of its immediate surroundings, chemical and physical conditions such as light, moisture, etc., and includes all other animals of its own and other kinds. See Chapter II.

119. Robins and bluebirds are really thrushes, although the recent classification places them in separate families.

120. The characters of minnows and other small stream fishes are given in the chapter on Fishes.

121. A cricket "sings" by rubbing its modified wing covers together. See Insects.

122. "Night-crawlers" are earthworms, commonly called "fishing worms."

123. Diving beetles, hellgrammites, and water bugs kill fishes.

124. The hellgrammite, or bass fisherman's bait, is the larva of the dobson fly. The insect spends one year and eleven months in the larval stage and then emerges into an adult after a short pupal period. The adult does not live for more than twenty-four hours. See text and Fig. 43.

125. Water striders or water skippers are bugs.

126. None of our native snakes spit poison.

127. Snakes do not "charm" people.

128. The shrike or butcher bird impales its surplus food on thorns.

129. The female water bug usually seizes an unwary male and glues her eggs on his back.

130. Dragon flies feed upon mosquitoes, flies, and other insects.

131. The mole cricket has front feet shaped like hands for digging.

132. Hornets, certain digger wasps, and mud daubers are beneficial. Many others are mentioned in the chapter on Insects.

133. Little flies, no matter how minute, are adults and never grow to larger size.

134. The "sowbug" or "pillbug" is a crustacean and is related to shrimps, crayfishes, and lobsters.

135. The cowbird is a native bird that commonly lays its eggs in the nests of other birds, although the cuckoo and others are also offenders of this sort at times.

136. The males of the scarlet tanager and goldfinch are brilliantly colored during the mating period and lose their gaudy coats when the breeding season is over. There are numerous others which do likewise.

137. Most native bats retire to caves and hollow trees where they hibernate during the winter months, although some species migrate as do birds.

138. Insects defend themselves by stings, poison glands, biting, odors, grotesque structures, etc.

139. Many animals hibernate during the winter months. Notable among these are: groundhogs, rats, mice, opossum, raccoon, bear, red squirrels, frogs, toads, salamanders, turtles, snakes, lizards, and insects.

140. Vireos, swifts, swallows, martins, nighthawks, whip-poor-wills, kingbirds, and numerous others capture insects in flight. They are not brilliantly colored, as a rule.

141. Most birds which capture insects in flight are dull colored.

142. Bedbugs, roaches, silver fish, book lice, fleas, and many other insects frequent households. See chapter on Insects.

143. Nearly all butterflies and moths are harmful in that they devour plant structures in their larval stages.

144. Sticklebacks are small fishes found usually in fresh ponds.

145. Fungi are beneficial in many ways. Some of them are valuable as food and most of them quickly cause the disintegration of dead organic matter and return its nutrient substance to the soil.

146. The worm usually has numerous segments and lacks a well-developed head and appendages.

147. Leeches, earthworms, tapeworms, and the threadworms or horse-hair worms found in water and in the soil are commonly found worms.

148. An insect has six legs.

149. A spider has eight eyes as a rule, although there are four-eyed and six-eyed species.

150. Not all spiders make webs. Many of them are roaming predators, while others are jumpers.

151. A measuring-worm is the caterpillar of a geometrid moth.

152. The distinction between a flicker and a meadowlark can be ascertained in any bird book or in the text.

153. Antennae or "feelers" are used as tactile, olfactory, auditory, and respiratory organs in the insect world.

154. Many house plants grow from bulbs. Among these are tulips, narcissi, hyacinths, and crocuses.

155. The animals we eat and those which supply milk, eggs, and honey are almost indispensable to humans.

156. Many trees such as sumac, sugar maple, sweet gum, sassafras, pin oak, and many others mentioned in the text have attractive autumn foliage.

157. Five flowering, ornamental shrubs are: rhododendron, forsythia, lilac, hydrangea, and azalea.

158. One group of primitive salamanders, the Caecilians, have minute scales embedded in the skin.

159. The largest salamander in the world is the Japanese giant sala-

mander (*Megalobatrachus maximus*) which attains a length of nearly five feet.

160. Many moths, notably the sphinx moths, do not spin cocoons.

161. Many moths are active during the daylight hours.

162. In rodents, the teeth continue to grow during the entire life of the animals and in the browsing mammals the teeth grow for a considerable period after maturity is reached.

163. The modification of insect appendages is discussed in the chapter on Insects.

164. Insect nymphs, naiads, and larvae which live in water breathe by means of gills, breathing tubes, and by direct absorption of oxygen. See Water life.

165. All adult water insects must come to the surface periodically for air.

166. Birds of prey can be identified by their talons and hooked bills.

167. The wings of birds do not vibrate vertically in flight. Although the wings do beat up and down in a way, the movement is partly backward and forward. See Clark's *Animals of Land and Sea.*

168. Hollow bones, stream-line form, and numerous air pockets in the feathers of birds make their bodies buoyant for aerial travel.

169. The plumage of water birds is oily and water runs off it without wetting the feathers which would render the birds flightless.

170. The legs of diving birds are located on the hind end of the body.

171. The legs of terrestrial birds are located nearer the center of the body.

172. Trees prepare for winter by shedding their leaves, storing sugars in the stem, and thus stopping all physiological and vegetative processes. The sap becomes concentrated and descends to the roots.

173. The raccoon washes its food before eating it.

174. Ermine is weasel fur.

175. The Baltimore oriole builds a hanging nest.

176. Moss on the side of a tree is not a sure sign of North.

177. The beaver does not use its tail as a shovel.

178. Hudson seal is muskrat fur.

179. The mongoose is the oriental destroyer of snakes. It has been introduced into the West Indies.

180. Caviar is fish eggs which have been prepared in a special process perfected by the Russians.

181. A horse gets up on its front legs so that it may look around as it arises. The horse is a descendant of a plains animal.

182. A cow gets up on its hind legs. It is descended from forest ancestors and vision in a forest is better near the ground.

183. Young ducks are ducklings; young geese are goslings; young swans are cygnets; and young turkeys are poults.

184. The disease commonly transmitted by rabbits is Tularemia.

185. The woodpecker has a barbed tongue.

186. The smallest American game bird is the sora rail.

187. A foal or colt has longer legs than a calf. The colts were originally born in open country where it was necessary for animals to run from danger. The ancestors of the calf had young which were spotted and these young were hidden in dense woods while the mothers browsed.

188. Raccoons, opossums, bats, many rats and mice, and numerous other animals are active only at night.

189. Carrion insects of many kinds, vultures, and magpies are notable eaters of carrion. Others are mentioned in the text.

190. Many brilliantly colored birds such as scarlet tanagers, goldfinches, and others lose their brilliant colors after the breeding season is ended.

191. A cotton-tail rabbit plucks hair from its body to line its nest.

192. Most mammals that are born naked are blind at birth and others such as cats and dogs are also blind when born.

193. The pileated woodpecker, the raven, prairie hen, heath hen, and a few others have become exceedingly rare. The passenger pigeon is extinct.

194. Countershading renders a protection to animals by neutralizing shadows, and is discussed fully in the chapter on Color.

195. The works of von Frisch, von Hess, Williams, Poulton, Peckham, and others show definitely that insects do discriminate among colors.

196. Millipedes and centipedes are described in the chapter on Arthropods.

197. Woodpeckers, chimney swifts, and nearly all other climbing birds use their tails as props.

198. A swallow has a much longer tail than a swift.

199. An electric light bug is the giant water bug which lives in water and emerges periodically at night when it is attracted to street lights.

200. The smallest North American mammal is the Virginia shrew, which is less than three inches long.

APPENDIX B

A LIST OF BIOLOGICAL SUPPLY COMPANIES

Materials needed for courses in Natural Science can be obtained from the companies listed below. Several of these dealers are equipped to furnish everything that is needed in all biological courses, while others specialize in apparatus or preserved material. A number of them publish excellent catalogs in which the latest devices for collecting and preserving are illustrated. Teachers are urged to write for catalogs because many improved methods of conducting general nature and biology courses can be learned from them.

The General Biological Supply Company publishes the *Turtox News* in which very many helpful suggestions regarding laboratory, field, and classroom teaching are presented regularly.

Ward's Natural Science Establishment publishes *Ward's Bulletin* which is also informative and helpful.

The Southern Biological Supply Company publishes *Research Studies* from time to time. These are excellent and helpful scientific treatises written in understandable language.

General Biological Supply House
761–763 East 69th Place
Chicago, Illinois

(Furnishes all requisites including collecting apparatus, live and preserved material of all kinds.)

Ward's Natural Science Establishment, Inc.
P. O. Box 24 Beechwood Station
Rochester, N. Y.

(Specialists in entomological supplies and equipment as well as preserved and mounted animals of all kinds.)

Denoyer-Geppert Co.
5235–5257 Ravenswood Ave.
Chicago, Illinois

(Charts, models, preserved material.)

Southern Biological Supply Co.
517 Decatur Street
New Orleans, La.

(Specialists in living and preserved marine and fresh-water organisms, as well as other material.)

Marine Biological Laboratory, Supply Dept.
Woods Hole, Mass.

(Marine material, living and preserved.)

Fisher Scientific Co.
Forbes Street
Pittsburgh, Pa.

(General laboratory equipment, glassware, and supplies.)

Alden H. Forbes Laboratories
Westview,
Pittsburgh, Pa.

(Preserved and living material. Specimen mounts, life histories, and microscopic slides.)

American Instrument Co., Inc.
Washington, D. C.

(Scientific measuring instruments.)

American Profession Supply Co.
Chicago, Illinois

(Glassware and laboratory equipment.)

Triarch Botanical Products
Ripon, Wisconsin

(Botany supplies.)

Western Biological Laboratory
University Place
Lincoln, Nebraska

(Biological material, living and preserved.)

Spencer Lens Co.
Buffalo, N. Y.

(Projection apparatus, microscopes, magnifiers, etc.)

Clay-Adams Co., Inc.
25 East 26th Street
New York City, N. Y.

(Charts, models, imported mounts.)

W. M. Welch Scientific Co.
1515 Sedgwick Street
Chicago, Illinois

(General apparatus and supplies for all sciences.)

Standard Scientific Supply Corp.
34–38 West Fourth St.
New York City, N. Y.

(Laboratory apparatus and supplies.)

Bausch and Lomb Optical Co.
Rochester, N. Y.

(Projection apparatus, microscopes, magnifiers, etc.)

Carl Zeiss, Inc.
485 Fifth Ave.
New York City, N. Y.

(Microscopes, magnifiers, photographic equipment.)

Biological Supply Co.
1176 Mt. Hope Ave.
Rochester, N. Y.

(Living and preserved material for biology courses.)

Carolina Biological Supply Co.
Elon College, North Carolina

(Marine organisms and general supplies.)

The Kauffman-Lattimer Co.
41 East Chestnut St.
Columbus, Ohio

(General supplies for biology courses.)

Central Scientific Co.
460 East Ohio Street
Chicago, Illinois

(Laboratory apparatus and general supplies.)

Chicago Apparatus Co.
1735-1743 No. Ashland Ave.
Chicago, Illinois

(Laboratory apparatus and general supplies.)

Eimer and Amend
Third Ave., 18th to 19th Streets
New York City, N. Y.

(Glassware, chemicals.)

Will Corporation
Rochester, N. Y.

(Electrical equipment.)

E. Leitz, Inc.
60 East 10th St.
New York City, N. Y.

(Microscopes, magnifiers, photographic equipment, etc.)

New York Biological Supply Co.
34 Union Square
New York City, N. Y.

(General biological supplies.)

INDEX

(Bold face numbers refer to pages on which illustrations appear.)

C

D

N

O

P